



ROD MACHADO'S GROUND SCHOOL

CONTENTS

Rod Machado's Ground School	5	Class 6: Landings	62
Meet Your Instructor	6	Your First (Mental) Landing	62
Class 1: How the Airplane		Landing Details	63
Remains Airborne	7	Playing with Power	64
May the Four Forces Be with You	7	Glidepath Adjustment If	
Flight Controls	10	You're Too Low	67
Ailerons	10	The Landing Flare	68
Elevator	11	Flap over Flaps	72
Straight-and-Level Flight	13	Landing using Flaps	75
Time for a Trim?	18	Class 7: Taxiing the Aircraft	78
Class 2: How Airplanes Turn	22	Taxi Thoughts	78
Rudder	26	Airport Markings	79
Class 3 - Climbs	31	Runway Lighting	81
Descents	34	Taxiway Markings	83
Beginning a Climb	35	Additional Runway Markings	88
You're on Your Way Up	36	Class 8: Stalls	91
Care to Waltz?	37	First, a Little Theory	91
What Goes Up... ..	37	Stall, Angle of Attack, and	
Things are Turning Up	41	How the Nose Knows	91
Time for a Turn Down	43	Stall at Any Attitude	
Class 4: Slow Flight	46	or Airspeed	94
The Wing and Its Things	46	Stop Flying; Start Stalling	96
Here's What You've Learned	58	Doing the Wrong Thing	
You're On Your Own	58	in a Stall	97
Class 5: Takeoffs	60	Doing the Right Thing in a Stall	97
		Departure Stalls	98

CONTENTS

Class 9: Steep Turns	99		
Steep Turn Aerodynamics	99		
What This Means to You	102		
2 G or Not To G	103		
The Tough Part	103		
A Touch of Class Before You're Out of Gas	104		
Class 10: The Traffic Pattern	107		
The Departure Leg	108		
Crosswind Leg	108		
The Downwind Leg	109		
Preparing for the Base Leg Turn	110		
Base Leg	110		
Final Approach	112		
Class 11: Crosswind Landings	115		
Crosswind Conundrums	115		
Crabbing	115		
One Wing Low	119		
Combo Crab and Wing Low to Go	120		
Class 12: VOR Navigation	121		
The Big Picture	121		
Your VOR Equipment	123		
How to Navigate using VOR	123		
Intercepting and Tracking a VOR Course	126		
		Flying from the VOR on a Selected Course	129
		Wind Correction while Tracking a VOR Course	130
Class 13: Step 1 of the Instrument Scan	135		
Attitude, Power, and Trim	135		
Straight-and-Level Flight from a Climb, Entering	138		
Descent from Straight-and-Level Flight, Entering	139		
Straight-and-Level Flight from a Descent, Entering	140		
Climbing and Descending Turns, Entering	140		
Class 14: Step 2 of the Instrument Scan	142		
Radial-Scanning the Primary Instruments	142		
Class 15: Step 3 of the Instrument Scan	151		
Trim using the VSI, and Monitor-Scan the Big-6 Instruments	151		

CONTENTS

Class 16: Instrument Approaches.. 155

VFR vs. IFR Flying 155

Instrument Flying:

The Big Picture 156

The Approach Chart 157

The VOR Approach 158

Flying the Santa Monica

VOR Approach 159

A Variation of the

VOR Approach 160

The Racetrack

Course Reversal 161

The Barb-Type

Course Reversal 162

The ILS Approach 164

Class 17: Flying an ILS Approach ... 168

The Constant Rate Descent 169

Radial-Scanning

Primary Instruments 172

A Few Important Secrets 173

Wind Correction on the Localizer 174

Class 18: Holding Patterns 177

Hold That Pattern! 177

Direct Entry 178

Parallel Entry 178

Teardrop Entry 179

Final Thoughts 180

Index 181

ROD MACHADO'S GROUND SCHOOL



Rod Machado is a professional speaker who travels across the United States and Europe delighting his listeners with upbeat and lively presentations. His unusual talent for simplifying the difficult and adding humor to make the lessons stick has made him a popular lecturer both in and out of aviation.

Rod has over 30 years experience in aviation and over 8,000 hours of flight time earned the hard way-one CFI hour at a time. Since 1977 he has taught hundreds of flight instructor revalidation clinics and safety seminars and he was named the 1991 Western Region Flight Instructor of the Year. He's flown as a corporate pilot and has been a flight instructor for over 28 years.

For six years, Rod wrote and coanchored ABC's Wide World of Flying. He is AOPA's National CFI spokesman and a National Accident Prevention Counselor appointed by the FAA in Washington D. C. His Private Pilot Handbook is a staple for thousands of people who are learning to fly. All of his books, along with buckets of aviation wisdom and wit, are available through www.rodmachado.com.

ROD MACHADO'S GROUND SCHOOL

Meet Your Instructor

I'm Rod Machado, your ground school instructor. I'm the fellow who is going to give you the essentials you need to make sense of what you see during your flight lessons (I just happen to be your flight instructor, too). So buckle up and adjust that classroom seat because we're going to learn a lot and have fun in the process.

Over the years, I've taught many people how to fly. My methods were straightforward. We'd review the concepts on the ground, hopped in the airplane for a flight lesson, and then discuss our accomplishments after landing.

We'll do the same here. I'll treat you as if you're learning to fly a real airplane in both the ground school classes and flight lessons. Of course, this isn't a real airplane, but it's pretty darn close, and these ground school classes are the homework before you step into the cockpit for your lessons. All I ask is that you complete the required homework before each lesson.

Homework is very important. One day, when I was in grade school, I didn't bring my homework to class. The teacher asked me why, and I said, "Ahh, the dog ate it." The savvy teacher responded by saying, "Rod, do you really expect me to believe the dog ate your homework?" I replied, "Well, I had to force him, but he ate it." Of course, I won't force you to do your homework; but if you do, I guarantee you'll learn real flying skills like everyone else I've taught.

There's no better way to learn than by doing, so let's get started with our ground school classes. You'll learn what you need as you go along instead of trying to learn isolated bits of information out of context. This way, you won't need to keep five pounds of facts swirling around in a three-pound brain.

CLASS 1: HOW THE AIRPLANE REMAINS AIRBORNE

We often use mechanical equipment without completely understanding how it works.

As a young bachelor, my parents gave me a vacuum cleaner for my birthday. Several months later, Mom called and asked, "Are you having trouble finding bags for your vacuum cleaner?" I said, "Bags? What bags?"

How was I to know the thing needed bags?

Technological ignorance has its advantages, but not when you're up in the air. You don't need a Ph.D. in aerodynamics to be a pilot, but a moderate-to-decent understanding of why an airplane stays airborne will prove helpful and life-sustaining. That's why this first ground school class is the longest. Don't worry; you won't need to have your eyeballs re-capped after reading it. But I do want you to read it all the way through. In order to fly a plane, you must first fill your brain (with a little bit of information, at least). This class is the place to start. Read, and be happy because this is an investment that will pay off big-time.

May the Four Forces Be with You

No, the four forces isn't a 1960s rock group. These forces are actually the things that pull and push on an airplane in flight. The four forces—lift, weight, thrust, and drag—are present any and every time a plane is airborne. Look at Figure 1-1, which shows the action of the four forces.

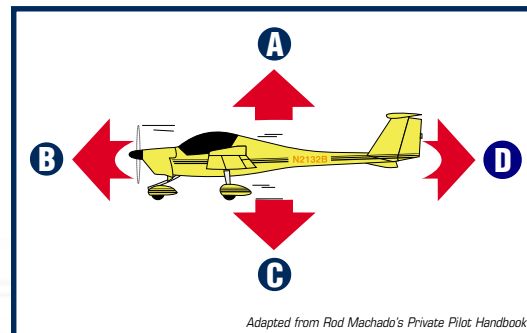


Figure 1-1. The four forces acting on an airplane in flight. A-Lift, B-Thrust, C-Weight and D-Drag

Of course, enormous arrows don't really protrude from the airplane. I know this will disappoint those of you who still expect the states to be colored blue and red and have lines drawn around their borders as you fly over them, but you'll get used to it. The arrows do serve to show that what

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we've got here is a highly competitive new game—four-way tug-of-war. Your job as pilot is to manage the resources available in order to balance these forces. Let's see what they're all about.

Lift is the upward-acting force created when an airplane's wings move through the air. Forward movement produces a slight difference in pressure between the wings' upper and lower surfaces. This difference becomes lift. It's lift that keeps an airplane airborne.

I discovered how lift works at four years of age during my first visit to church. The collection plate passed in front of me, and I picked out a few shiny items. My grandfather chased me around the pew, and I thought, "Wow, church is fun!" Picking me up by my sweater, Grandpa held me suspended four feet off the ground and toted me outside. It was the lift from Grandpa's arm, precisely equaling my weight, that kept me airborne. Wings do for the airplane what Grandpa's arm did for me—provide the lift to remain aloft.

Weight is the downward-acting force. It's the one force pilots control to some extent by choosing how they load the

airplane. With the exception of fuel burn, the airplane's actual weight is difficult to change in flight. Once airborne, you should not be burning cargo or acquiring extra passengers (or losing them for that matter). Unexpected discharge of passengers while in flight is a violation of some FAA rule, so please don't do it.

In unaccelerated flight (when the airplane's speed and direction are constant), the opposing forces of lift and weight are in balance.

Thrust is a forward-acting force produced by an engine-spun propeller. For the most part, the bigger the engine (meaning more horsepower) the greater the thrust produced and the faster the airplane can fly—up to a point. Forward movement always generates an aerodynamic penalty called drag. Drag pulls rearward on the airplane and is simply the atmosphere's molecular resistance to motion through it. In plain English (which pilots and engineers rarely use), it's wind resistance. Few things are free with Mother Nature. As Confucius might say, "Man who get something for nothing not using his own credit card."

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Thrust causes the airplane to accelerate, but drag determines its final speed. As the airplane's velocity increases, its drag also increases. Due to the perversity of nature, doubling the airplane's speed actually quadruples the drag. Eventually, the rearward pull of drag equals the engine's thrust, and a constant speed is attained.

My high school VW Bug knew these limits well (it's called a Bug because that's the largest thing you can hit without totaling the car). The Bug's forward speed is limited by its engine size. With four little cylinders (only three of which worked at any one time), this VW simply wouldn't go faster than 65 mph. Figure 1-2 shows the results of maximum thrust meeting the equal and rearward pull of drag at this speed.

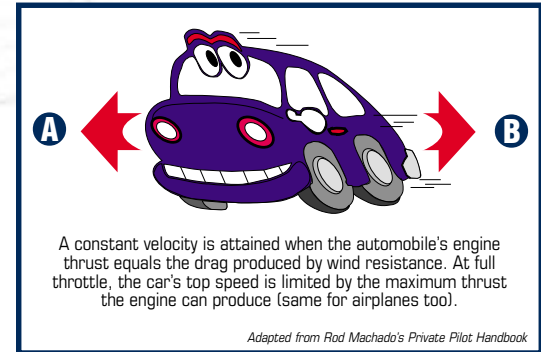


Figure 1-2. An automobile's A-Thrust, produced by engine power and B-Drag, caused by resistance of air molecules

Maintaining a slower speed requires less power, since less drag exists. At any speed less than the maximum forward speed of the car, excess thrust (horsepower) is available for other uses, such as accelerating around other cars or perhaps powering a portable calliope if you are so inclined.

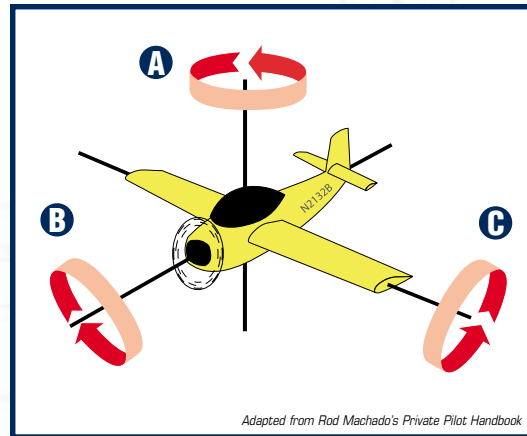
The same is true of airplanes. At less than maximum speed in level flight, there's power (thrust) to spare. Excess thrust can be applied to perform one of aviation's most important maneuvers—the climb. With this introduction, I think it's time for you to learn a little about the airplane's flight controls.

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Flight Controls

If you're ready-made pilot material, you've been patiently licking your chops waiting for the discussion on flight controls.

Gandhi would applaud your patience (but Gandhi isn't here, so I will). Figure 1-3 shows the three imaginary axes of the airplane. By use of the flight controls, the airplane can be made to rotate about one or more of these axes.



Adapted from Rod Machado's Private Pilot Handbook

Figure 1-3. The three axes of an airplane, A-Vertical Axis (Yaw), B-Longitudinal Axis (Roll), C-Lateral Axis (Pitch)

The longitudinal, or long, axis runs through the centerline of the airplane from nose to tail. Airplanes roll, or bank, about their longitudinal axis.

A sideways pass in football is called a lateral pass. Similarly, the lateral axis runs sideways through the airplane from wingtip to wingtip. Airplanes pitch about their lateral axis.

The vertical axis of the airplane runs up and down from the cockpit to the belly. Airplanes yaw about their vertical axis. Think of yawing motion as yawning motion. In the morning, you yawn by standing and stretching vertically, rotating right and left, waiting for those vertebrae to kick in.

Now we're ready to examine each of the three main flight controls that cause an airplane to move about its axes.

Ailerons

Ailerons are the moveable surfaces on the outer trailing edges of the wings. Their purpose is to bank the airplane in the direction you want to turn. When the control wheel is turned to the right, as shown in Figure 1-4, the ailerons

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simultaneously move in opposite directions (this doesn't mean they're broken, either). The left wing aileron lowers, increasing the lift on the left wing. The right wing aileron raises, decreasing the lift on the right wing. This causes the airplane to bank to the right.

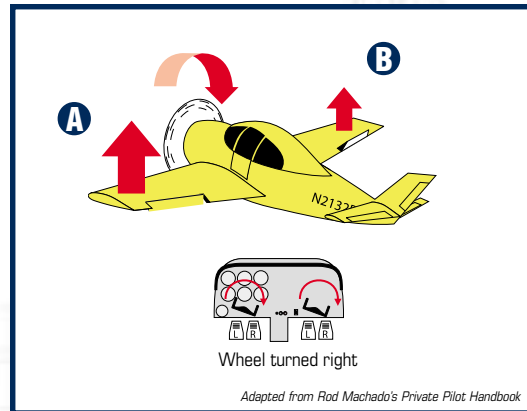


Figure 1-4. Banking to the Right. How ailerons bank the airplane. A-More lift with a lowered aileron, B-Less lift with a raised aileron.

When the control wheel is turned to the left, as shown in Figure 1-5, the left wing aileron raises, decreasing the lift on the left wing. The right wing aileron lowers, decreasing the lift on the right wing. This causes the airplane to bank to the left.

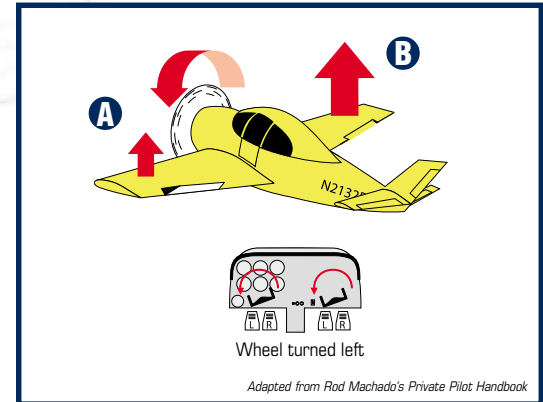


Figure 1-5. Banking to the Left. How ailerons bank the airplane. A-Less lift with a lowered aileron, B-More lift with a raised aileron.

Ailerons allow one wing to develop more lift and the other to develop less. Differential lift banks the airplane, which tilts the total lifting force in the direction you want to turn.

Elevator

The elevator is the moveable horizontal surface at the rear of the airplane (Figure 1-6). Its purpose is to pitch the airplane's nose up or down.

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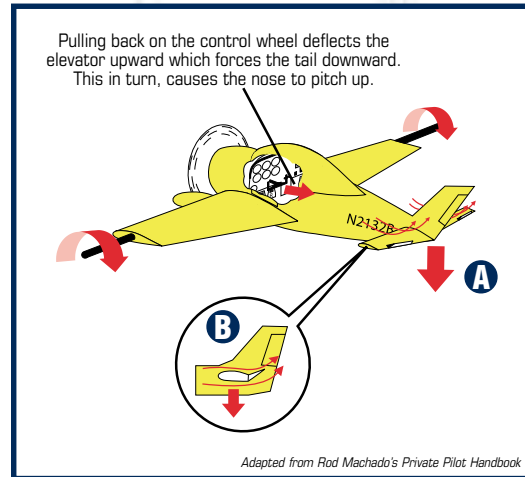


Figure 1-6. How the Elevator Control changes the airplane's pitch. A-Tail movement (down). B-Tail moves down & nose moves up.

The elevator control works on the same aerodynamic principle as the aileron. Applying back pressure on the control wheel of the airplane, as shown in Figure 1-6, deflects the elevator surface upward.

Lower pressure is created on the underside of the tail, which moves it downward, and the nose of the airplane pitches up.

The airplane in Figure 1-7 shows what happens when the control wheel is moved forward. The elevator surface moves down, thus creating lower pressure on the top side of the tail.

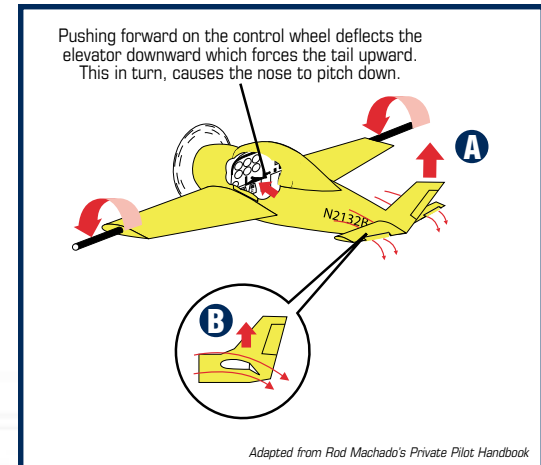


Figure 1-7. How the Elevator Control changes the airplane's pitch. A-Tail movement (up). B-Tail moves down & nose moves up.

This causes the tail to rise. The nose rotates about the lateral axis in a downward direction. Simply stated, to pitch up, pull the control wheel back; to pitch down, move the control wheel forward.

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There's also a third flight control, the rudder, which controls yaw around the vertical axis. We'll discuss this later on, but for now, I want to make sure you know I didn't forget about it.

Now that you've acquired a basic idea of how the flight controls work, let's put our brain in the plane and discuss how to perform a useful flight maneuver: straight-and-level flight.

Straight-and-Level Flight

You're about to practice straight-and-level flight, one of aviation's most fundamental maneuvers. Does this sound like two separate maneuvers instead of one? Well, it is. Straight flight means the airplane's nose remains pointed in one direction and the wings are parallel to the earth's horizon. Level flight means the airplane doesn't gain or lose altitude.

Figure 1-8 shows what straight-and-level flight looks like from the left seat where you, the pilot, normally sit. Don't worry if the picture shows us headed for a distant mountain. I'm with you, and I'm good at avoiding mountains. In fact, it's my specialty.



Figure 1-8

How to Tell You're Going Straight

Okay, how do you know you're actually flying straight and level? The easiest way to tell is to look over the instrument panel and out the windscreen (the front window), as shown in Figure 1-8. It appears that the top portion of the instrument panel is approximately parallel with the earth's distant horizon. This implies that your wings are not banked, which means you're flying straight ahead and not turning.

There is, however, another way to tell if you're flying straight. You can press the hat switch on your joystick (the hat switch is the button that sticks straight up out of the middle, near your opposable thumb—you should have one of these thumbs. If not, you must have missed a day at

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evolution school.) If you look out the left or right window, as shown in Figure 1-9, you'll notice the position of each wing relative to the earth's horizon. In straight flight, both wings should be the same distance above the horizon (refer to the horizon, not the mountains).

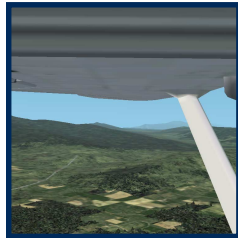


Figure 1-9

Having the Right Attitude

In real airplanes, I prefer that my students almost strip the gears in their neck by looking right and left out the windows. This helps them check the wing's position and keeps their eyes focused out the cockpit looking for traffic. No, I don't mean automobile traffic, either. I mean airplane traffic. In the simulator, however, it's inconvenient to keep shifting views to the left and to the right. So you'll use the attitude indicator to help maintain

straight-and-level flight. The attitude indicator is located at the top of the six main flight instruments directly in front of you (Figure 1-10).



Figure 1-10

The attitude indicator is an artificial representation of the real horizon. Just as its name suggests, the attitude indicator displays the airplane's attitude (its upward or downward pitch and the bank the wings make with the horizon). The upper half of the attitude indicator is blue (like the real sky, unless, of course, you fly in Los Angeles), the bottom half is brown (like the surface below us). The thin white line between these colors is

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the artificial horizon line. Pilots use the attitude indicator when they can't see the earth's horizon because of restrictions to visibility or when it's inconvenient to look at the wing tips (which will usually be your situation when flying the simulator).

By moving the joystick to the left, the airplane banks to the left, which dips the left wing downward toward the ground, as shown in Figure 1-11. This is how you begin a left turn. Notice that the miniature (orange-winged) airplane in the attitude indicator also appears to dip its left wing toward the ground. Mechanically speaking, it's really the background of the attitude indicator that moves and creates a picture of the airplane's attitude. Nevertheless, you can always tell which way you're banking by determining which one of the small orange wings in the attitude indicator dips toward the ground (this is easy since you only have two choices).

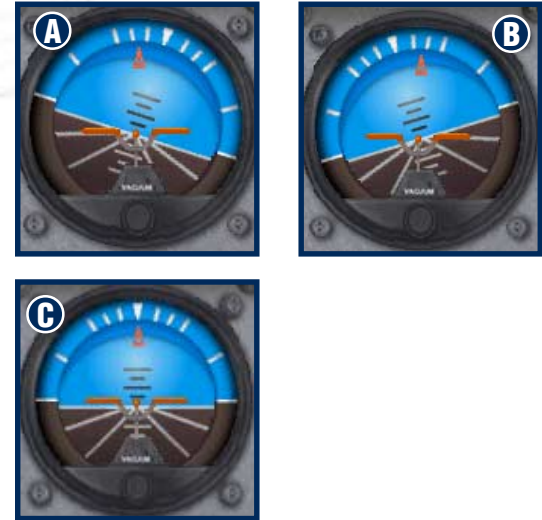


Figure 1-11

By gently moving the joystick to the right in the same manner first described, the attitude indicator will indicate a right turn. Now the right wing dips toward the ground, as shown in Figure 1-11B. Moving the joystick to the right or left until both wings are parallel to the artificial horizon line (Figure 1-11C) returns the joystick to its center (default) position and returns the airplane to straight flight, as shown in Figure 1-11C. After all, if the wings aren't banked, the airplane isn't turning.

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Know Where You're Heading

There is one more way to know if you're flying straight. This involves using the airplane's heading indicator, as shown in Figure 1-12.



Figure 1-12

Figure 1-12 shows the airplane's heading indicator (sometimes called the directional gyro). It's found in the middle of the bottom row of the six main flight instruments that we'll be discussing soon. Think of the heading indicator as a mechanical compass that shows which way your airplane points. Notice the numbers on the face of the heading indicator. Add a single zero to any number on the face to get the airplane's

actual heading. In other words, 6 is really a heading of 60 degrees (spoken as zero-six-zero degrees). The number 33 is actually a heading of 330 degrees. (When we say that aloud, we say "three-three-zero degrees" for extra clarity. It's important to be extra clear when you're flying.) These numbers appear at 30-degree intervals. Between these numbers are 5- and 10-degree heading increments.

To fly a specific heading, simply turn the airplane in the shortest direction to the heading desired. For example, turn the airplane until the nose of the white airplane in the heading indicator points to the letter W for West (this is a heading of 270 degrees). Of course, if the heading remains constant, then you're flying straight and thus, not turning. This is another way to identify that you're flying straight.

Now that you understand the straight portion of straight-and-level flight, let's move on to the level portion of this maneuver.

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Making Sure You're on the Level

Let's talk about what happens to your altitude when you pitch the airplane's nose up or down. When you pitch the airplane up by applying back pressure on the joystick, the attitude indicator's miniature airplane also points upward toward the sky (the blue), as shown in Figure 1-13A.



Figure 1-13

Look at the altimeter, which is located directly to the right of the attitude indicator (Figure 1-13B). The biggest hand (the hundred-foot hand) will normally move clockwise when the nose is raised. And, just like the hands of a watch, clockwise movement means something is increasing. In this case, it's your altitude.

Directly below the altimeter is the vertical speed indicator (VSI). Its needle also deflects upward, showing a rate of climb (Figure 1-13C). These are additional indications that you're climbing and not maintaining level flight.

When the joystick is returned to its center position, the airplane will begin to settle back into level flight (assuming the airplane is properly trimmed—we'll talk about this shortly).

When you pitch the airplane downward, the attitude indicator's miniature airplane points toward the surface (the brown color), as shown in 1-14A.

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Figure 1-14

The altimeter's hands will begin to unwind (rotate counterclockwise), indicating a loss of altitude.

The VSI will also show a rate of descent as its needle deflects downward. It's safe to say that if the big hand of the altimeter stops moving and the VSI needle indicates zero, then you're in level flight. In fact, this is precisely how pilots confirm that their airplane is in level flight.

It takes practice to keep these needles stationary (in real life, they're always moving just a tiny bit). The average private pilot does a great job if he or she remains within 100 feet of a chosen altitude. Unfortunately, when I was a student, I found it much easier to keep changing the target altitude at which I wanted to be (until, of course, I finally perfected this skill).

In the Interactive Lessons, you'll practice maintaining straight by keeping the attitude indicator's miniature airplane (the orange wings) parallel to the artificial horizon line. If a wing dips right or left, you'll raise it by moving the joystick in the opposite direction.

You'll also get some practice at maintaining level flight by keeping the altimeter's hundred-foot hand stationary. It shouldn't move. If it does, then you'll use the joystick to change the pitch slightly until it stops moving. This will be the pitch attitude required for level flight.

Time for a Trim?

Airplanes are subject to an assortment of aerodynamic forces. Some try to pitch the nose up; others try to pitch it down. Engine power, weight placement, and lift are just a few of these forces. What does this mean to you? Well, if the airplane wants to pitch forward, you can't sit there pulling back on the joystick for the entire flight. Applying continuous pressure on the control wheel to maintain pitch attitude means your arms would tire quickly (Schwarzenegger would be proud of you, but I wouldn't). Fortu-

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nately, airplanes have something known as a trim tab to take the pressure off the control wheel (and off the pilot!). Let's look at how the trim tab works, and then we'll talk about how to use it.

How Trim Tabs Work

A trim tab is a small, moveable surface attached to the main surface you want to control (in this case, it's the elevator). Figure 1-15A shows the trim tab and the trim wheel that's used to change the trim tab's position (in the real airplane, the wheel is usually located between the two front seats or on the lower portion of the instrument panel).

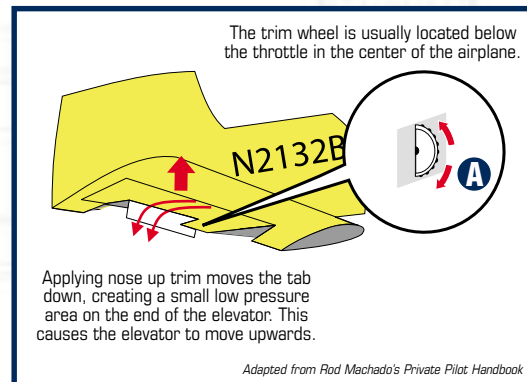


Figure 1-15A. How Elevator Trim works. A-Nose down.

Moving the trim tab creates a slight pressure difference on the end of the control surface to which it's attached. Just enough pressure is created to keep the primary control surface in the desired position without having to hold the control wheel in place. Notice that the trim tab moves in a direction opposite to the primary control surface it affects. If you want the elevator to deflect upward (as if you're pulling back on the wheel in a climb), the trim tab must move down, as shown by Elevator A in figure 1-15A.

To maintain a downward deflection of the elevator (as if you're in a descent), the trim tab must move upward, as shown by Elevator B in Figure 1-15B.

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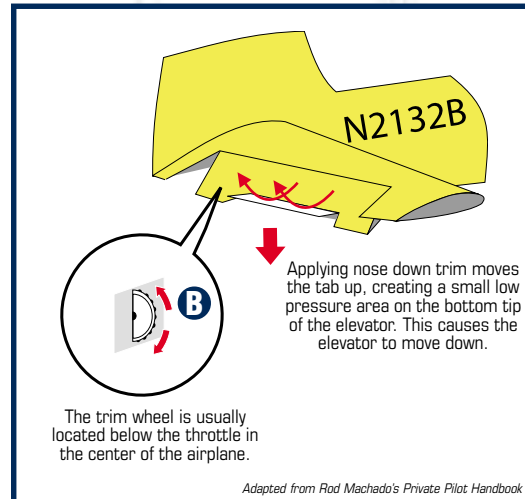


Figure 1-15B. How Elevator Trim works. B-Nose up.

Think of trim as an imaginary hand that holds the airplane in the desired attitude while eliminating the pressure you apply to the joystick. The trim control may be found on your joystick in the form of small wheels or buttons. If you don't have a trim button on your joystick, you can use two keys on the number pad to trim the airplane for the proper pitch attitude. Key number 1 provides nose-up trim, and key number 7 provides nose-down trim.

Here's how you should trim an airplane for straight and level flight. First, check to see if the airplane is already properly trimmed. Do this by easing up on the pressure being applied to the joystick. Then, watch the VSI's needle. If the needle shows a climb (rotates upward), the airplane needs nose-down trim. Apply a little forward pressure on the joystick to return to level flight, then press 7 once for a little nose-down trim (or use the nose-down trim button). Once done, release the pressure on the joystick and see what happens.

The more you push the trim button, the more trim you apply. So be patient. You may have to repeat this same process several times until the VSI's needle remains relatively horizontal, near the zero climb rate value.

If the VSI's needle shows a descent (rotates downward), apply a little back pressure on the joystick to return the airplane to level flight. Then press 1 on the number pad a few times for nose-up trim (or use the nose-up trim button). Once done, release the pressure on

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the joystick and watch the VSI's needle response. Repeat the process as necessary until the airplane neither climbs nor descends.

I prefer to use the VSI's needle for trimming, since it's very sensitive. I don't mean that it will cry if you tell it that it's ugly. I mean that its needle is sensitive to small changes in pitch. This makes it easier to detect deviations from level flight. In a future lesson, I'll show you how to use the VSI's needle for trimming in a climb or descent.

Many airplanes have trim for bank control, called aileron trim. You may even have this as part of your joystick assembly. Bank trim is sometimes necessary when the wing's fuel load is unbalanced or if you have heavier passengers sitting to one side of the airplane.

Regardless of how well the airplane is trimmed, it may oscillate up or down slightly, varying its altitude by perhaps 100 feet up or down. That's the way airplanes are. Each one likes to do its own thing and may vary slightly in altitude and heading even when properly trimmed. Let them go, unless they wander too far off. Your job is to make the airplane as easy as possible to fly so you have more time to think, plan, plot, and scheme your way to safe simulator flying.

You should be proud of yourself for accomplishing your first ground school session. Hey, I'm proud of you! Now it's time for some interactive flight training. Go to **Learn to Fly**, and choose **Student Lesson One**. Then in the next ground school lesson, I'll introduce you to the basics of turns.

CLASS 2: HOW AIRPLANES TURN

There are many misconceptions in aviation. For instance, there are pilots who think propwash is a highly specialized detergent. And a select few think that when an instructor says, "Okay, taxi," that they should call a Yellow Cab. As a young student pilot, an FAA inspector asked me how an airplane turns. I looked at him and said, "With the wheel, sir." He clutched his chest and shook his head in disbelief. I admit that my answer was a little off and that he was a tad upset (the foam around his mouth and his eyebrows merging with his hairline were good clues). Just so you don't have any of these problems, let's examine what causes an airplane to turn, and then look at how you can perform this nifty little maneuver.

Airplane A in Figure 2-1 shows a view of an airplane in straight and level flight.

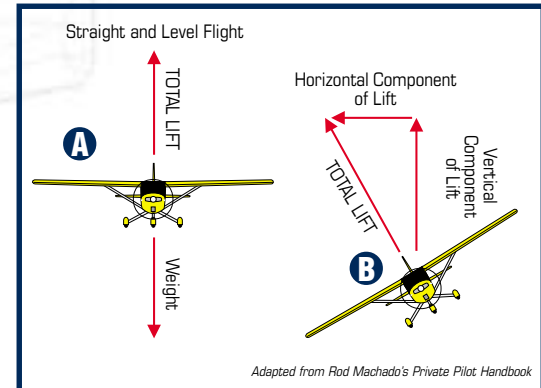


Figure 2-1. How an Airplane Turns. Banking the airplane causes the lift force to tilt, which pulls the airplane in the direction of the bank. Technically, it's the horizontal component of the tilted lift force that makes the airplane turn.

From this vantage point, lift acts vertically, pulling upward on the airplane and keeping it suspended in flight. Of course, if lift can pull upward, it can also pull a little to the left or right. When it does this, the airplane turns.

Airplane B in Figure 2-1 shows the total lift force in a banked airplane. Part of the lift force pulls the airplane up (the vertical component of lift), and part pulls the airplane in the direction of the turn (the horizontal component of lift). You can use your imagination and visualize two separate and smaller forces making up the

CLASS 2: HOW AIRPLANES TURN

total lifting force. (There are those crazy arrows again. You will not see these on a real airplane, so enjoy them while you can.) The arrows represent the forces of lift.

Always remember that it's the horizontal component that causes an airplane to turn—it pulls the airplane in an arc. Therefore, the larger the angle of bank, the greater the horizontal component and the quicker the airplane can turn.

Now that you know what makes an airplane turn, let me play the role of Socrates, the philosopher, and ask you an important question. (Don't mind the bed sheet I'm dressed in. If, however, I show up wrapped in a mattress, that means were ready to practice landings.) The question is, "How do we tilt lift so as to make the airplane turn?"

The answer is, "With the ailerons."

If you said, "With the wheel," I promise not to have a heart attack. In fact, turning the wheel or deflecting the joystick (that is, banking the airplane using ailerons) is exactly how we tilt the total lifting force and start a turn.

To turn, deflect the joystick (when I say deflect, I mean to move it slowly to the right or left) in the desired direction of the turn and roll the airplane until reaching the desired bank angle. Then, return the joystick to its neutral (center) position, and the airplane usually remains established at this bank angle. If the airplane drifts from the desired bank, give the joystick a nudge or two to maintain the bank angle.

Let me roll myself up in that sheet and play Socrates again by asking, "From the inside of the cockpit, how can you tell how steeply you're banking?" After all, you can't have another pilot follow you around just to tell you what your bank is. Here's a better way.

Figure 2-2 shows the attitude indicator that we learned about earlier. At the top of the attitude indicator, immediately to the right and left of center, are three white bank marks. Each mark indicates 10 degrees of bank, up to 30 degrees. Beyond the 30-degree mark are the 60-degree and 90-degree bank marks. To establish a 30-degree bank, roll the airplane until a white bank mark (the third one from the top) rests over the little orange triangle.

CLASS 2: HOW AIRPLANES TURN

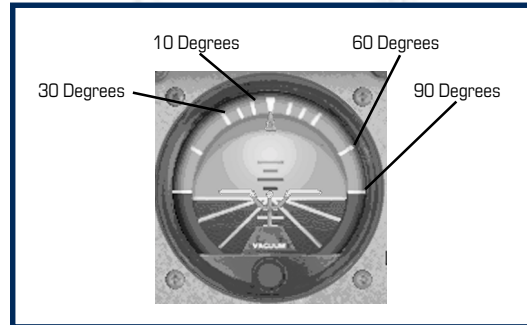


Figure 2-2. Bank Lines.

Not too tough, is it? But what if you want to bank at 15 or 45 degrees? Here's how it's done.

Figure 2-3 shows two white diagonal lines angled downward from the middle of the attitude indicator. These are bank lines for 15 and 45 degrees of bank, respectively. If you roll the airplane to the right until the attitude indicator's miniature airplane (the one with little orange wings) is parallel to the first diagonal line, as shown in Figure 2-3, then you're in a 15-degree bank. A 45-degree bank is accomplished by gently rolling the airplane until the miniature airplane's wings are parallel to the second diagonal line.

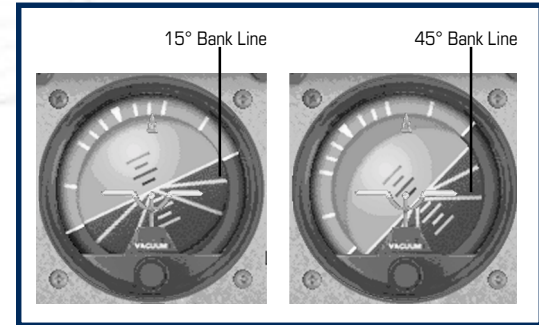


Figure 2-3.

Now there's one more thing you need to understand before you're ready to proceed to the Interactive Lesson on turns.

In aviation, it's important to remember that you never get something for nothing. This is especially true when making turns.

Tilting the total lift force while in a turn means less lift is available to act vertically against the airplane's weight (refer back to Airplane B in Figure 2-1). The airplane responds by moving in the direction of the momentarily larger force—downward, in the direction of the weight. We compensate for this by increasing our lift slightly whenever we enter a turn. This is done by applying a little back pressure on

CLASS 2: HOW AIRPLANES TURN

the joystick (that's back pressure on the joystick, not pressure you generate on your back by digging your heels into the airplane's carpet). Later on, you'll understand that back pressure increases the wing's angle of attack, thereby increasing the wing's lift slightly. Unfortunately, this increase in angle of attack also increases the drag, which slows the airplane down. In a shallow-banked turn (somewhere around 30 degrees or less), this decrease in speed isn't a concern. Steeper turns (45 degrees or more) may require the addition of power to prevent the airspeed from decreasing too much.

Let's take a look at the attitude indicator again and see how we can use it to help us calibrate the amount of back pressure we will use when entering a turn.

Observe the position of the attitude indicator's miniature airplane (especially the orange ball between the wings). In straight-and-level flight, the miniature airplane (and orange ball) rests almost directly over the artificial horizon line, as shown in Figure 2-4. In a bank, however, it's hard to identify the airplane's pitch on

the attitude indicator since the miniature airplane is no longer aligned with the artificial horizon line. Therefore, use the position of the orange ball in relation to the artificial horizon line as a pitch reference in a turn.

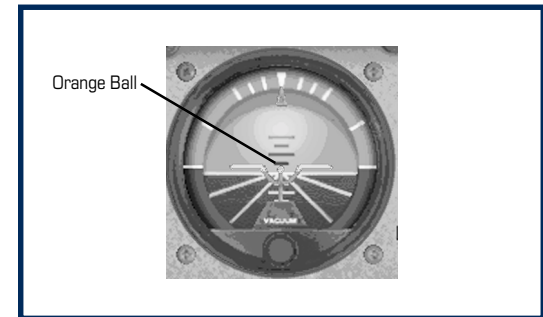


Figure 2-4. Mini-airplane rests almost on horizon bar in straight and level flight.

In order to hold altitude in a 15-degree and a 30-degree bank turn, you must slightly increase the airplane's pitch. Figure 2-5 gives you a basic idea of how much this pitch must increase.

CLASS 2: HOW AIRPLANES TURN

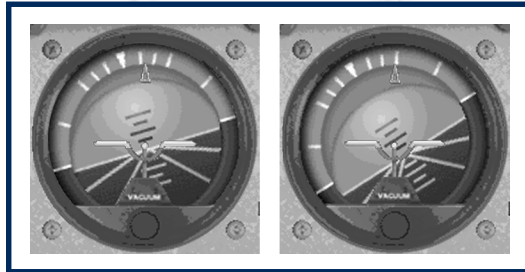


Figure 2-5.

The point you want to remember is that *steeper turns require an increase in pitch to maintain altitude*. When rolling out of a turn back into straight flight, you must release the back pressure, thus reducing the pitch to that required for level flight. You'll learn more about why we must increase the pitch in a turn in the upcoming section on slow flight. For now, when rolling into or out of a turn, make whatever pitch-up adjustment is necessary to maintain altitude. In steeper turns, be prepared to pull back a little more on the joystick to keep the VSI's needle reading zero and the altimeter's big (hundred-foot) hand steady. Use the orange ball's position relative to the artificial horizon

line to determine the airplane's pitch while banked. And remember to lower the pitch when returning to straight-and-level flight.

Since I promised you that we'd cover the rudder usage in a little more detail, here's an extra bit of information for those of you with rudder hardware.

Rudder

The rudder is the moveable vertical surface located at the rear of the airplane. Its purpose is to keep the airplane's nose pointed *in the direction of the turn*—not to turn the airplane! Remember, airplanes turn by banking. Rudder simply corrects for the forces that want to twist the airplane in a direction other than the direction it wants to turn (there are several forces that do this, but we won't discuss them here. If you'd like to do a little extra credit, go to the end of this lesson and read the section titled "Extra Credit - Adverse Yaw").

Flight Simulator 2002 comes with an autorudder feature that keeps the nose pointed in the proper direction when making a turn. Therefore, if you don't

CLASS 2: HOW AIRPLANES TURN

have rudder pedals, this simulated airplane will always fly coordinated. In other words, an appropriate amount of rudder will always accompany any aileron input. Of course, real airplanes don't have an autorudder feature (although some student pilots think of their flight instructor as the autocoordinator). Therefore, if you decide to take flight training in an actual airplane, you'll learn all about the rudder and how to use those pedals. Just in case you happen to have rudder pedal hardware, you might want to keep on reading to learn more about using it.

Think of a rudder as a vertical aileron located on the tail of the airplane. A right or left deflection of the rudder foot pedals changes the angle the vertical stabilizer makes with the wind, causing the airplane to yaw about its vertical axis. This yawing motion keeps the airplane's nose pointed in the direction of the turn.

Applying the right rudder pedal, as shown by Airplane A in Figure 2-6, forces the tail assembly to swing in the direction of lower pressure. As the tail moves, the airplane rotates about its vertical axis. Application of right rudder pedal yaws the

nose to the right. Applying left rudder pedal (I'll just say rudder from now on), shown by Airplane B, yaws the nose to the left (surprising, huh?).

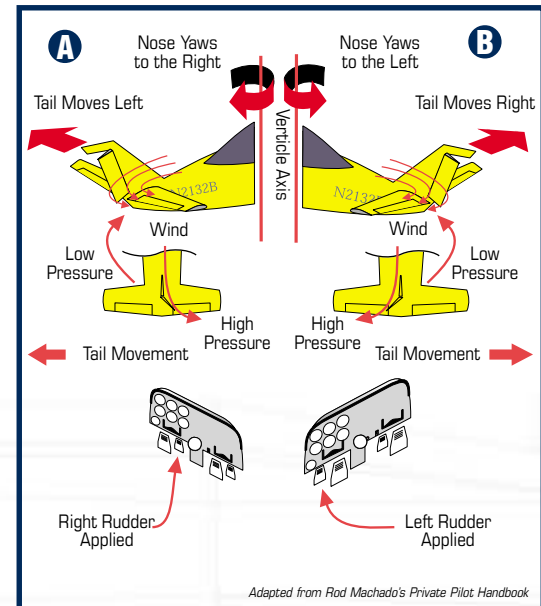


Figure 2-6. How Rudder Compensates for Adverse Yaw.

A Little More on Rudder Usage

Let's suppose you opened your birthday present and found a set of rudder hardware for Flight Simulator 2002. You lucky

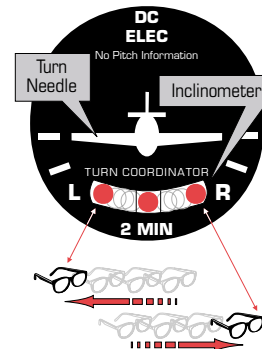
CLASS 2: HOW AIRPLANES TURN

person, you! (Or, you might just have a joystick with the rudder function built in. Try twisting it!) It won't be long after you hook it up that you stop and ask yourself, "Hey, when do I use the rudder?" The answer is, *any time you use the ailerons* (such as when you're making a turn).

If you don't use rudder in a turn, part of the airplane will try to go in a direction different from the direction of bank. This is not a pretty sight, and your instructor's eyebrows will rise so high that they will scratch his or her back. An easy way to remember this is: right turn, right rudder; left turn, left rudder. Feet and hands move together.

Now the question foremost in your upper-brain is "How much rudder is enough?" Good question. Figure 2-7 shows an inclinometer, also known as the ball, as a part of another instrument called the turn coordinator (located on the instrument panel).

The movement of the ball corresponds to the movement of the sunglasses on your car's dashboard. The same force that moves the glasses also moves the ball. The ball, however, slides more easily than the glasses. The ball's deflection from center identifies when the airplane's nose is pointed other than in the direction of turn. Rudder is used to move the ball back to the centered position.



Adapted from Rod Machado's Private Pilot Handbook

Figure 2-7. The Turn Coordinator.

The little white airplane in the turn coordinator shows the direction of the turn, while the ball tells you if the proper amount of rudder is being applied. The ball is free to roll right or left within the glass tube. Any inappropriate rudder use (or lack of use) applies an unnecessary side force to the airplane. This deflects the ball in much the same way sunglasses scoot across your car's dash when rounding a sharp corner. Your job is to keep the ball centered by using the rudder.

CLASS 2: HOW AIRPLANES TURN

Figure 2-8 shows an airplane in a turn. Airplane A's nose is pointed outside the turn (probably because of insufficient right rudder or too much right aileron being applied). The ball and the airplane slip to the right, toward the inside of the turn. In other words, you need to point the nose slightly to the right for a precisely aligned turn. By adding enough right rudder to align the airplane in the direction it's turning, the ball returns to the center, as shown by Airplane B.

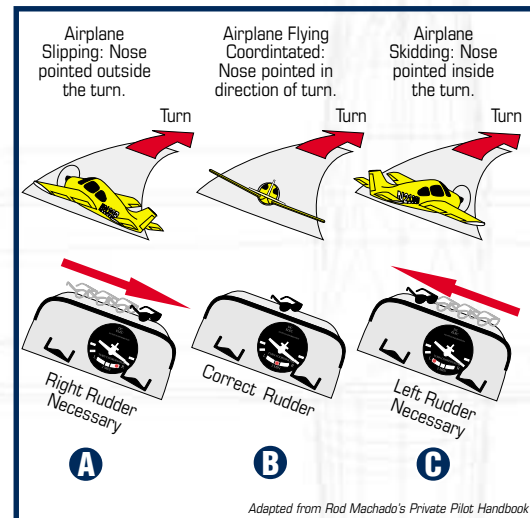


Figure 2-8. Slipping and Skidding in an Airplane.

Airplane C's nose points toward the inside of the turn (probably because too much right rudder is applied or insufficient right aileron is used.) The ball and the airplane skid to the left, toward the outside of the turn. Adding a little left rudder keeps the nose pointed in the direction the airplane is turning and centers the ball.

Simply stated, if the ball is deflected to the right or left of center, add enough right or left rudder (respectively) to center the ball. Sometimes you'll hear your instructor say, "Step on the ball!" This is simply your instructor's way of telling you to add right rudder for a right-deflected ball or left rudder for a left-deflected ball. Don't even think about placing your foot on the turn coordinator; or your instructor will question you about your SAT scores. Don't put marbles in your shoes either.

When entering a turn, aileron and rudder are applied simultaneously and in the same direction. This is what pilots mean when they refer to flying coordinated. Aileron establishes the degree of bank,

CLASS 2: HOW AIRPLANES TURN

and rudder keeps the nose pointed in the direction of turn. If the ball is centered during this process, we say that the controls are properly coordinated.

Extra Credit - Adverse Yaw

Adverse yaw is the reason airplanes are equipped with rudders. When banking to the right, the aileron on the left wing lowers, causing that wing to lift up. While the lowered aileron increases the lift on the left wing, it also causes a slight increase in drag. "Wait a minute," you say, "I didn't order any drag with my lift." True, but this isn't a pizza, either. Mother Nature always accompanies lift with a little drag—like a chaperone on a high school date (which would be a real drag).

In a right turn, the aileron on the left wing goes down to lift that wing. The wing rises, but the slight increase in drag pulls the left wing aft a little. This has the effect of pulling (or yawing) the airplane's nose adversely to the left as the airplane banks to the right. Thus, the name adverse yaw.

Obviously, if you're banked to the right, you want the nose to point in the same direction you're banking, don't you? This is where rudders come in handy.

By keeping the ball in the inclinometer centered, you're properly correcting for adverse yaw. In this condition, the airplane is being flown with the proper coordination.

Remember, adverse yaw affects the airplane as it rolls into or out of a bank. Therefore, more rudder pressure is needed when rolling into or out of a bank. Once you're established in a turn, you often can neutralize the rudder and the nose should remain pointed in the direction you're headed. (Later, you'll learn about situations in which it's necessary to keep a little rudder pressure applied in a turn.)

Of course, without rudder pedal hardware or a rudder joystick, you'll most likely operate the airplane with the auto-rudder feature active. It simply makes no sense to deactivate this feature of Flight Simulator 2002 and let the airplane wobble all over the sky.

You've done well so far. Why don't you go practice in Student Lesson Two? Then, it's time to progress to something uplifting, like climbs. I'll also take you on a downer (a good one, that is) by teaching you how to make descents in the airplane.

CLASS 3: CLIMBS

In the fifth grade, my teacher asked me to come to the front of the class and name the parts of speech. I walked up, turned around, and calmly replied, “Lips, tongue, lungs, and oxygen.” Well, apparently that wasn’t the answer she was looking for.

Speech has its basic components, and so does aviation. So far, we’ve practiced two of the four most important fundamentals of flight: straight-and-level flight and turns. Now it’s time to practice the final two: climbs and descents.

One of aviation’s biggest misconceptions is that airplanes climb because of excess lift. This is similar to believing that putting hand lotion in your airplane’s fuel tank will make your landings smoother, softer, and younger looking.

Airplanes climb because of excess thrust, not excess lift. Let’s return to the example of a car on the road to learn a little bit more about why this is.

A car traveling uphill is similar to an airplane in a climb. The only difference is that you (the pilot) choose the slope of the hill you climb. This is done using the elevator control that we discussed earlier.

On a level stretch of road, the maximum forward speed of the car with full power is 65 mph (Figure 3-1, Car A). As we move up a hill (Car B), the speed drops to 50 mph. An even steeper hill slows the car to 40 mph (Car C). The limited horsepower of the car’s engine simply can’t match the drag caused by wind resistance plus the rearward-acting weight as the hill steepens, so the car slows. A bigger engine or a redesign of the car to produce less wind resistance are the only options that could help this tired old machine climb the hill faster.

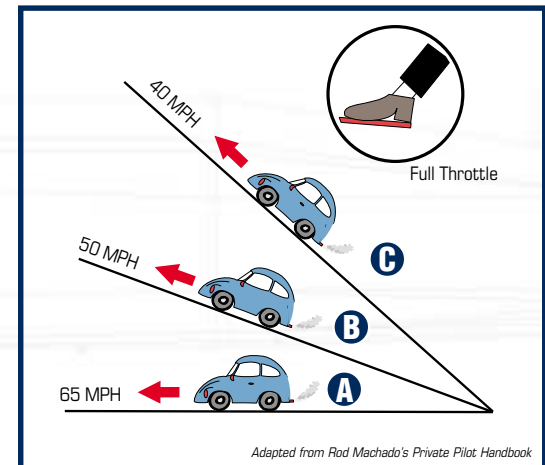


Figure 3-1 Power and Climb Angle. Even with full power, the car starts to slow down as the hill steepens

CLASS 3: CLIMBS

The same analysis works, up to a point, for an airplane attempting to climb a hill in the air (Figure 3-2). Let's say our airplane has a maximum speed of 120 mph in straight-and-level flight with full throttle (Airplane A). (Think of airplane throttles as being similar to automobile throttles, except that an airplane throttle is hand-operated).

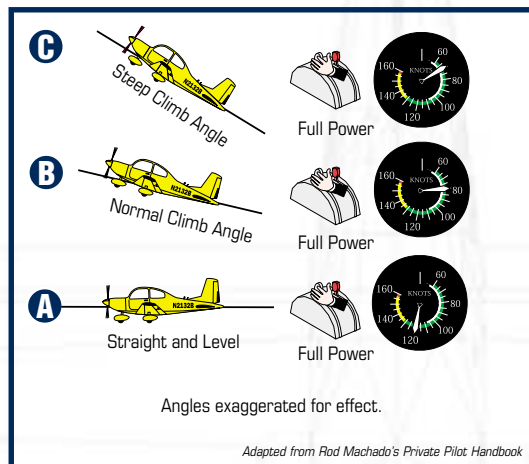


Figure 3-2 Power, Climb Angle and Airspeed. Even with full throttle (maximum power), the airplane slows down as it attempts to ascend a steeper hill. Pilots adjust their climb angle (hill size) by selecting an altitude that gives them a specific climb airspeed

You push in for more power and pull out for less. Applying slight back pressure on the elevator control points the airplane's nose upward (Airplane B). This causes the airplane to climb a shallow hill, and the speed decreases to, let's say, 80 mph, just as it did in the car. Attempting to climb a steeper hill (Airplane C) slows our speed down to 70 mph. We can't climb the hill we just selected faster than 70 mph because we don't have the extra horsepower (thrust) to do so.

As we continue to steepen the angle of climb, our airspeed decreases further, just like the car's speed did. Here, however, is where the airplane goes its own way. Airplanes need to maintain a minimum forward speed for their wings to produce the lift required to stay airborne. Ever wonder why airplanes need runways? Same reason long-jumpers do. Airplanes (and long-jumpers) must attain a certain speed before they can take flight.

This minimum forward speed is called the stall speed of the airplane. It's an important speed that changes with variations in weight, flap setting, power setting, and angle of bank. It also varies among airplanes (no need to worry because later

CLASS 3: CLIMBS

I'll show you how to recognize when you're near a stall). As long as the airplane stays above its stall speed, enough lift is produced to counter the airplane's weight, and the airplane will fly.

If the stall speed of Airplane C (Figure 3-2) is 60 mph, then climbing at a slightly steeper angle will result in insufficient lift for flight. We call this condition a stall. Done unintentionally, it leads to such primitive linguistic sounds as, "Uh-oh," "Yipes," and "Ahhhhh," as well as, "I think I need to have my chakras balanced." Needless to say, in a real airplane, these sounds make passengers reluctant to ever fly with you again. This is why an upcoming lesson will be spent finding out about stalls and doing them (intentionally, that is). Instructors have special biological filters installed that keep them from making these sounds on those rare occasions when you unintentionally stall the airplane. That's why we are sometimes referred to as certified flight instructors.

What you need to know is that airplanes with a lot of power (like jet fighters) can climb at steep angles; those with limited power, however, must climb at less steep angles.

Knowing it's extra thrust and not extra lift from the wings that is responsible for the climb allows you to draw some interesting conclusions. For instance, anything that causes the engine to produce less power prevents you from achieving your maximum rate of climb. Among the things resulting in less power production are high altitudes and high temperatures. Not applying full power for a climb is also another condition that gives you less power, but that's a no-brainer, right?

At this point, you should be asking an important question. I certainly don't mean questions of the Zen koan type, such as, "What is the sound of one cylinder firing?" or "If an airplane lands hard in the forest and nobody is there to hear it, does it really make a sound?" A good question for you to ask is, "How can I determine the proper size hill for my airplane to climb?" Let's find out.

Airplanes have a specific climb attitude (steepness of hill) that offers the best of all worlds—optimum climb performance while keeping the airplane safely above its stall speed. You can determine the proper climb attitude for your airplane by referring to its airspeed indicator.

CLASS 3: CLIMBS

With climb power applied (usually full throttle in smaller airplanes), the pitch attitude is adjusted until the airspeed indicates the proper climb speed. In the Cessna 172, we'll use a speed of 75 knots for all our climbs. Sometimes, however, pilots climb at airspeeds slightly faster than 75 knots. No, they don't do this because they want to get somewhere faster. They do it because it provides them with better over-the-nose visibility.

Raising the nose of the airplane results in a slower airspeed; lowering it picks up the pace. Where you place the nose—that is, the attitude you select or how steep you make the hill—determines what happens on the airspeed indicator. Unlike the ground-bound world, pilots decide how steep the hills in the air are going to be (within limits of course!). With just a little experience, you'll be able to determine the correct size hill (nose-up attitude) by looking out the front window instead of having to rely solely on the airspeed indicator.

When I was a student pilot, it seemed that any specific airspeed was the one place on the dial where the pointer never

went. I was not gifted with much coordination as a youngster. My reflexes were so slow, I was almost run over by two guys pushing a car with a flat tire. I'm a living exhibit that one can be a competent pilot even without the coordination and reflexes of a 13-year-old Olympic gymnast.

Descents

While engine power moves a car uphill, gravity pulls it down. Without your foot on the throttle, the car's downward speed is determined by the steepness of the hill it's descending. The steeper the hill, the faster it goes. If the hill becomes shallower, then the speed decreases. If the hill becomes too shallow, then some power is necessary to maintain sufficient forward speed.

Airplanes can also move downhill without power (Figure 3-3). Just lower the nose, and you'll get what appears to be a free ride (it isn't, but let's not get into that). You can adjust the nose-down pitch attitude using the elevator control and descend at any (reasonable) airspeed you want.

CLASS 3: CLIMBS

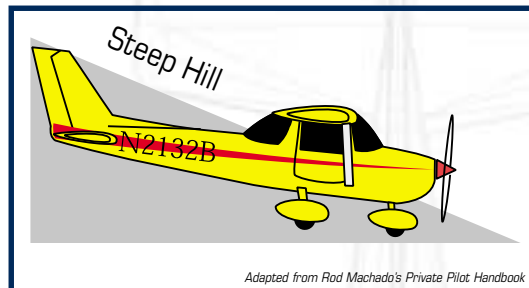


Figure 3-3 An Airplane in Decent

You now have the answer to a question I guarantee every first-time passenger will either ask or want to ask you: “What happens if the engine quits?” The airplane becomes a glider, not a rock.

Unlike climbing, you may elect to descend within a wide range of airspeeds. There are, however, many factors to be considered, such as forward visibility, engine cooling, and the structural effects of turbulence on the airframe. (All of these items are discussed thoroughly in my *Private Pilot Handbook*, which is available from my Web site. You can link directly to it from the Library & Help page in Flight Simulator 2002.)

However, during the last portion of the landing approach (known as final approach), you should maintain a specific

airspeed. Usually, this speed is at least 30 percent above the airplane's stall speed. When preparing to touch down, excess airspeed or erratic control forces often lead to difficulty in making a smooth landing (it's also the reason pilots make good-humored fun of one another).

Now it's time to talk about how to do climbs and descents from inside the cockpit.

Beginning a Climb

Flying is no fun if it's all talk and no action. So let's take a look at the actions involved in entering a climb. Let's assume that your airplane is in straight-and-level flight at cruise power with an airspeed of 100 knots. Entering the climb requires that you raise the nose to climb attitude and simultaneously add climb power. After all, it makes sense to get the airplane up in the air as fast as is reasonable to take advantage of favorable winds and the better view (among other reasons). So in the Cessna 172, you'll always add full power to climb. Then, you'll apply enough nose-up trim to hold the airplane in this attitude.

CLASS 3: CLIMBS

As soon as you begin raising the nose, you'll notice that the airspeed drops and the vertical speed indicator begins to show a climb. This is one sure sign that you're climbing. When the people on the ground start to look like ants, that's another clue (unless you're really looking at ants).

Figure 3-4 shows the airplane climbing at 85 knots and 500 feet per minute.



Figure 3-4

You're on Your Way Up

Engineers (not the kind that drive trains) tell us that our Cessna 172 climbs most efficiently at 74 knots. Since the airplane in Figure 3-4 is at 85 knots, how do you get the airplane slowed down to 74 knots while continuing to climb at full power?

The answer is to raise the airplane's nose (increase the steepness of the hill you're climbing) to a slightly higher climb attitude. Hold it there, and watch the response on the airspeed indicator. Adjust the pitch up or down slightly until the airspeed indicator shows 74 knots. (75 is okay, too.) Be patient. Airplanes have inertia and take a moment or two to settle into a new speed once the pitch is changed.

To maintain a 75-knot climb speed, you should show a pitch of approximately 13 degrees on the attitude indicator, as shown in Figure 3-5 (for now, we'll use the attitude indicator for our pitch and bank reference since it's difficult to see the real horizon over the instrument panel in a flight simulator). The attitude indicator's vertical calibration lines are worth five degrees each, so you read

CLASS 3: CLIMBS

them (from bottom to top) as 5, 10, 15, and 20 degrees of pitch. Thirteen degrees of pitch would be just below the third line up.



Figure 3-5

Of course, the pitch for a climb may vary slightly. All that matters, however, is that you find the proper pitch that gives you the climb airspeed you want.

Care to Waltz?

Now you know the secret to climbing an airplane. Therefore, the next time you want to climb, follow this procedure: Raise the nose to approximately 13 degrees pitch-up on the attitude indicator,

add full throttle, and trim the airplane to maintain this attitude. It's as simple as that. Then, adjust the pitch slightly (perhaps only a degree or two) to give you the airspeed you want. Think of entering a climb as a three-step waltz. Think: one, two, three, one, two, three, or attitude, power, trim (unfortunately, when I waltz, between every count, I'm constantly saying, "Oops, sorry about your feet"). Change the attitude, change the power, then trim the airplane once it's stabilized at its new attitude.

Of course, you may elect to climb at a slightly faster speed. This often makes it easier to look over the instrument panel (so I can see and avoid other airplanes). When a rapid, efficient climb to altitude isn't necessary, find the airspeed that gives you both a good climb rate and a reasonable view over the panel.

What Goes Up...

If you keep climbing, you'll eventually climb out of the atmosphere, right? Not really, but you still need to know how to get down (and I don't mean learning to dance, either).

CLASS 3: CLIMBS

Think of descending in an airplane as you would going down a hill in a car. First, as the car points down a steep hill, you normally take your foot off the accelerator and coast downward. The steepness of the hill determines the car's eventual speed. Steep hills result in faster coasting speeds, while shallow hills result in slower coasting speeds. Airplanes work similarly.

Figure 3-6 shows an airplane with the power reduced to flight idle. In a sense, this airplane is coasting down a hill. The airspeed is stabilized at 80 knots in this figure. Now, let's change the steepness of the hill.



Figure 3-6

Pitch Change Means Airspeed Change

Let's see how a small change in pitch affects the airspeed. Without readjusting the trim, if you lower the nose slightly (make a steeper hill), you'll find an attitude that produces an airspeed reading of 90 knots. Do this by referring to the attitude indicator. By making a slight pitch adjustment—perhaps one-half of a degree, one degree, or even two degrees—and holding it, you'll notice the airspeed increase.

Eventually, the airspeed will indicate 90 knots and the attitude indicator will show a pitch attitude similar to that shown in Figure 3-7. If you want to descend at this speed, trim the airplane to maintain this attitude.

CLASS 3: CLIMBS



Figure 3-7

If you were to raise the nose (make a shallower hill), you would find an attitude that produces an airspeed reading of 70 knots. Figure 3-8 shows the attitude needed to produce this airspeed.



Figure 3-8

This is how you should control the air-speed during a descent. Raise or lower the pitch attitude using the vertical calibration on the attitude indicator. Make a small change, and watch the result. Remember to be patient as the airplane slowly changes its speed.

Controlling your airspeed by adjusting your pitch this way is important, especially as you prepare for a landing. After all, you'll need to fly at different speeds when making your landing approach. By

CLASS 3: CLIMBS

making changes in pitch, you can descend at any airspeed you want. Just remember to use trim to maintain the airplane at the desired attitude and thus, the desired airspeed.

Finally, here's a little secret that only skilled pilots seem to know. When the airplane is properly trimmed for a specific airspeed, it should maintain that airspeed even if you change power (many factors affect this, so the airspeed may vary just a little.) This is an important concept when you think about it. If you're preparing to land and the airplane is trimmed for a specific speed, all you need to do is adjust power to maintain the desired glidepath. In other words, the airplane should maintain the speed for which it was last trimmed. Okay, you've talked me into it. Let's talk just a bit about changing descent rates.

Changing Descent Rates

What if you want to descend at the same airspeed but at a slower descent rate (a smaller reading on the VSI)? Well, here's your chance for power. (Sorry, I mean engine power. No world domination today!) Power has a direct bearing on your rate of descent.

At 80 knots, with the power at flight idle, the airplane descends at approximately 700 FPM (Figure 3-9). Suppose, for example, you're approaching to land and need less of a descent rate to make it to the runway. What do you do?



Figure 3-9

Increase your power to a higher value, say 2100 RPM, and adjust the pitch slightly to maintain 80 knots. Retrim if necessary.

Your instruments should look like those in Figure 3-10. With this slight increase in power, the airplane descends at 300 FPM. Of course, as more power is

CLASS 3: CLIMBS

added, the airplane will stop descending. If you give it even more power, the airplane will fly level or even start climbing at 80 knots.



Figure 3-10

At this stage of your training, it's a good time to agree on how you'll control the airplane. Power (throttle position) should be your means of adjusting the rate of descent (what the VSI reads). The airplane's pitch attitude (controlled by the joystick) is your means of maintaining a specific airspeed. In a climb, you'll always use the maximum allowable power (usually full throttle) while adjusting the

airplane's attitude using the joystick for the airspeed desired. Since you're familiar with the procedure for making climbs and descents, let's combine these with the skills we developed in Class 2.

Things are Turning Up

Suppose we want to combine climbs and descents with turns. Specifically, let's examine how to enter a 20-degree right-banking turn while established in a climb, then roll into straight-and-level flight. Here's how you might do it.

First, establish the climb. Increase the pitch to a 13-degree nose-up attitude, as shown in Figure 3-11, add full power, and trim. Then, you'll roll into the desired bank. The secret here is to use the attitude indicator's orange ball as the pitch reference. Since the orange wings won't be aligned with the horizon, use the orange ball as a pitch reference, and use the attitude indicator's orange pointer as the bank reference.

CLASS 3: CLIMBS



Figure 3-11

When climbing (descending, too), it's best to begin leveling off when you're within 50 feet of your desired altitude. A 50-foot lead helps prevent overshooting or undershooting the target altitude. If you want to level off at 4,000 feet, then enter level flight when you read 3,950 on your altimeter. At this point, you'd lower the nose and roll out into a straight-and-level flight attitude.

Yes, the power is still set at maximum, and that's good. Let the airplane accelerate to cruise speed (unless you specifically want to fly at a slower speed). Then reduce power to a cruise setting of approximately 2200 RPM.

Once the airspeed stabilizes, trim for this attitude, as shown in Figure 3-12.



Figure 3-12

Well, that's how you do it. Believe it or not, that wasn't necessarily a simple maneuver. Remember, the secret to going from one attitude to another (such as from straight and level to a climb) is to do it like a waltz: Attitude, power, and trim. You adjust the attitude to a known value that puts your airplane in the ballpark for a climb (13 degrees for a climb at 80 knots). Then you adjust the power (you'll climb with full power in this

CLASS 3: CLIMBS

airplane). And finally, you provide enough trim to hold this attitude. The formula of attitude, power, and trim is the secret when making any pitch change.

Time for a Turn Down

Suppose you're at 4,000 feet and want to descend to 2,500 feet while in a left turn at 20 degrees of bank. To make this maneuver a little more challenging, do it at 90 knots. Here's how it's done.

First, you roll into a 20-degree turn to the left.

Then, you reduce power to flight idle.

Next, you lower the nose to an attitude that you suspect gives you an airspeed of 90 knots (you'll notice that when you reduce power, the nose will automatically want to lower on its own. Therefore, you'll probably have to apply a little back pressure on the joystick to keep it from descending too quickly). Since 3 degrees positive pitch gives you 80 knots, perhaps you attain 90 knots at 1 degree positive pitch (a slightly lower attitude). Remember, because you're in a turn, you use the attitude indicator's orange ball as the pitch reference, as shown in Figure 3-13.

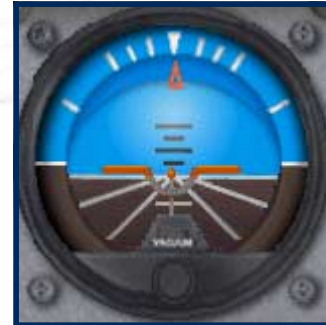


Figure 3-13

When you're at 2,550 feet (a 50-foot lead above 2,500), put the airplane in the attitude for straight-and-level flight.

Then, you increase power to a cruise setting of 2300 RPM, and trim when the airspeed stabilizes. Attitude, power, and trim, right?

Now you know how to make climbs, turns, and descents, as well as perform straight-and-level flight. Yes, you understand the basics. Now you need practice. I'm cutting you loose to practice in Student Lesson Three.

CLASS 3: CLIMBS



Figure 3-14

You've learned the basics of moving the airplane through the air. Next, we're going to learn all the little things that allow you to get it down on the runway. In fact, our next tutorial deals with flying at slower speeds, just like the speeds you'll fly at during a landing approach.

Figure 3-14 shows a typical altimeter found in most airplanes. It has three hands, which is how many you'll wish you had sometimes when things get busy in the cockpit. The shortest hand points to numbers representing the airplane's

Reading the altimeter is similar to reading a watch. I say this with caution knowing that some readers have been raised on digital watches and no longer know what it means when Mickey's little hand is on the 3 and his big hand is on the 12. Some may not even know which way Mickey's hands are supposed to turn.

height in tens of thousands of feet. The medium, thicker hand represents altitude in thousands of feet. The long, thin hand represents the airplane's altitude in hundreds of feet.

The easiest way to read an altimeter is to read it just like you would a clock. For instance, if Altimeter A in Figure 3-14 were a clock, what time would it read? Yes, it would read 3 o'clock. Since Altimeter A isn't a clock, it shows an altitude of 3,000 feet. The long (hundreds) hand points to zero hundred feet, and the medium (thousands) hand points to 3,000 feet.

If Altimeter B were a clock, what time would it say? It would read 3:30, or half past 3 o'clock. As an altimeter, it reads half past three thousand, or 3,500 feet.

CLASS 3: CLIMBS

The long (hundreds) hand points to 500 feet, and the medium (thousands) hand points to between 3,000 and 4,000 feet. Thus, the altitude is 500 feet past 3,000 feet (3,500 feet).

What time would it be if Altimeter C were a clock? It looks like it would be somewhere around a quarter to seven. More precisely, the long (hundreds) hand shows 800 feet, and the medium (thousands) hand points a little shy of 7,000 feet. Therefore, the altimeter reads 800 feet past 6,000 feet (6,800 feet). Not too tough, is it?

Try reading Altimeter D like a clock. What time is it? Yes, it looks like it's 3:00, but take a closer look at the very short (ten thousands) hand. This hand points a little past a value of 1, meaning you need to add 10,000 feet onto the value shown by the altimeter's medium and long hands. Thus, Altimeter D indicates an altitude of 13,000 feet.

A child's pinwheel spins as a result of the air blowing on it. In case you haven't noticed, airplane propellers are nothing more than big pinwheels for big kids. The pinwheel effect is responsible for RPM values that change from their preset positions as the airspeed changes. For instance, whenever you set the throttle to a new RPM value, the RPM reading will change as the airplane's airspeed changes. Why? The propeller reacts to changing airspeed like a pinwheel reacts to wind. This spins the prop artificially fast or prevents it from spinning to its full potential until the airspeed stabilizes. This often requires resetting the RPM once, or perhaps twice, to achieve the final setting you want. The pinwheel effect is associated with fixed-pitch propellers (which is the kind on our simulated airplane). Later on, you'll learn about constant-speed propellers that change their pitch to maintain a specific RPM.

CLASS 4: SLOW FLIGHT

Okay, here's the deal. I'm going to stick you in an airplane that's capable of doing 120 knots—twice as fast as the cars on the freeway below—and I have only one request: I want you to fly as slow as you can. Sounds reasonable, right? Not really. This is like asking an Indy racecar driver not to take his machine out of first gear. There is, however, a good reason for flying slowly.

The practice of slow flight is the proving ground in which you prepare for aviation's biggest event: landing. After all, you don't want to land at cruise speeds, because airplanes weren't designed to maneuver on the surface at high velocities. You don't want to burn the tires off the rims, do you? (Just kidding, but it's not far from the truth.) In general, the slower you are upon touchdown, the easier it is to control the airplane on the runway.

Additionally, airplanes can't fly too slowly, or they'll cease flying and start falling (this is called stalling, but it has nothing to do with the engine stopping, as you'll later learn). That's why I want you to feel comfortable operating at slower speeds so you'll know where the dangers are.

And, as you'll eventually discover, it's sometimes necessary to follow slower airplanes. You need to know how to adjust your airspeed to prevent chewing up their tail feathers. These are only a few of the reasons we practice slow flight. It's an important maneuver. Let's get started by discussing how airplane wings develop lift.

The Wing and Its Things

Defining the Wing

In ground school many years ago, my instructor asked me about the origin and definition of the word "wing." I replied, "Ma'am, I think it's Chinese and means 'the arm of a bird'." She mumbled something about why many animals eat their young at birth and then went to the dictionary to look up the definition. Wing was defined as "a moveable, paired appendage for flying." She looked at me and said, "Well, what does that sound like to you?" I said, "Well, ma'am, that sounds like the arm of a bird to me." We agreed to disagree, even though I was right.

CLASS 4: SLOW FLIGHT

The wing has several distinct parts. These are the upper cambered surface, lower cambered surface, leading edge, trailing edge, and chord line (Figure 4-1).

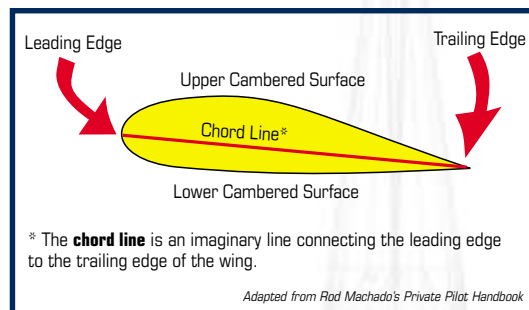


Figure 4-1. The Five Components of a Wing

Notice that the upper cambered (meaning curved) surface seems to have a greater curve to it than the lower cambered surface. This isn't accidental. In fact, this is so important that we'll talk about it in detail shortly.

Perhaps the only term whose definition isn't intuitively obvious is the chord line. The chord line is an imaginary line connecting the leading edge with the trailing edge. Believe me, there is no line inside the wing that looks like this. It's only imaginary, just like the arrows showing

the four forces. When the shoe salesperson points to your foot and says, "Your toe is here," you want to respond by saying, "Thanks, I've been looking for that." In reality, he or she is pointing out the position of something not visually obvious. The chord line does something similar. Given the wing's curved surfaces, it's difficult to tell which way the wing points. Since engineers don't like uncertainty, they agreed that the chord line will represent the general shape of a wing.

How the Wing Works

To understand lift, you must visualize how the wing attacks the air. Aeronautical engineers talk about the wing contacting, or attacking, the air at a specific angle. This occurs in much the same way a pit bull attacks a mailman—mouth first. What part of the wing does the attacking? Is it the leading edge? Is it the trailing edge? Or is it the bottom of the wing? This is where the definition of chord line becomes useful.

Because wings come in variable sizes and shapes (just like pilots), it is sometimes difficult to determine exactly how and where the wind strikes the wing. Fortunately, the chord line substitutes as a general reference for the shape of the

CLASS 4: SLOW FLIGHT

wing. If I say that the wind blows onto the wing at an 18-degree angle, I'm saying that the angle between the wind and the chord line is 18 degrees (Figure 4-2). This distinction, although seemingly trite, is as important to an engineer as tightly stitched pant seams are to a matador. Only one more definition needs be absorbed before the secrets of lift are revealed. That term is called the relative wind (which is not a reference to an uncle who tells long stories without inhaling).

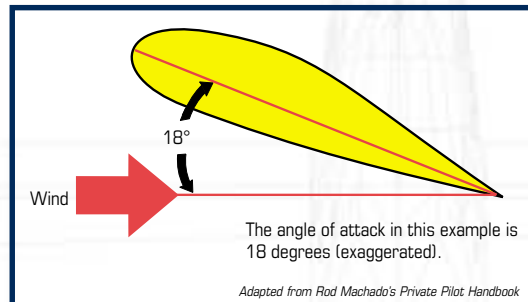


Figure 4-2 Angle of Attack. The angle of attack is the angle between the chord line and the relative wind (this is the wind that is blowing on the wing).

Relative Wind

Movement of an airplane generates wind over the wing. This wind is called the relative wind because it is relative to (or results from) motion. For instance, in Figure 4-3, no matter which way the jogger runs, he feels wind in his face that's relative (opposite and equal) to his motion.

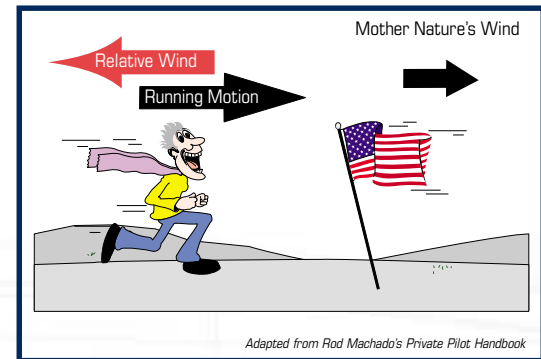


Figure 4-3 Relative Wind. The relative wind is wind resulting from an object's motion. Despite the actual wind blowing from behind, the jogger feels wind on his face as a result of his running motion. Relative wind is relative (opposite and equal) to the movement of an object.

CLASS 4: SLOW FLIGHT

Relative wind is movement-generated wind. To illustrate this point, stick your hand out the window of a moving automobile (keep all other body parts inside, please). You'll feel wind blowing opposite the motion of the car. Drive a car backwards on the freeway, and you will feel wind and hear a lot of horns blowing from directly behind you (you'll also attract the police). Relative wind is movement-generated wind that's equal and opposite to the motion of the airplane.

Move the airplane forward, as shown by Airplane A in Figure 4-4, and wind blows on its nose. Move the airplane up or down a hill, and wind still blows on its nose (Airplanes B and C). Drop an airplane, and the wind blows on its belly (Airplane D). As far as Airplane D is concerned, the wind is blowing on its belly despite the level attitude.

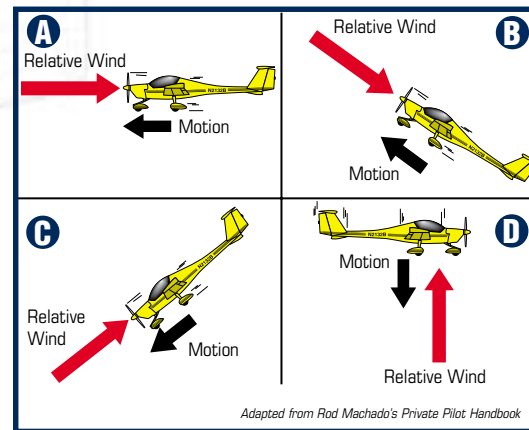


Figure 4-4 All illustrations show the relative wind is opposite and equal to the motion of the airplane.

Relative wind blows from a direction that's opposite the direction of airplane motion, irrespective of what direction the airplane is pointed. The following point is so important, I want you to put one finger in your ear. Go ahead, do it before reading any further! I want you to do this because I don't want this information to go in one ear and out the other. The important principle to remember is that relative wind is independent of which way the airplane's nose is pointed. Relative wind is opposite in direction and equal to the airplane's velocity. Let's see how the wing actually attacks the wind to develop lift.

CLASS 4: SLOW FLIGHT

Attacking the Air

Hunting is a sport to some people. It's also a sport where your opponent doesn't know it's a participant. Attacking an animal means that the hunter must point his weapon precisely at the prey. The hunter looks through the gun sight and sees the path of the bullet. An airplane is unlike a gun (and a car) in that its vertical climb path is different from its incline (the direction it points upward). Remember that 750-foot tower off the end of the runway? On takeoff, if you point your airplane slightly above the top of that obstacle (like a rifle sight), it's unlikely that you're going to clear it. In fact, the only thing being cleared is the area—as the firemen try to talk you down from the side of that tower. Remember, airplanes with limited thrust have shallower climb paths—unlike some fighter jets.

The most important principle to understand here (put that finger back in the ear) is that the nose (therefore the wing) can be pointed on an incline that's different from the actual climb path. An angle exists between the amount the wing is inclined and its climb path (you'll soon see why). Remembering that the relative wind

is always equal and opposite to the flight path, it's more precise to say that an angle exists between the chord line and the relative wind. This angle is known as the angle of attack (Figure 4-5).

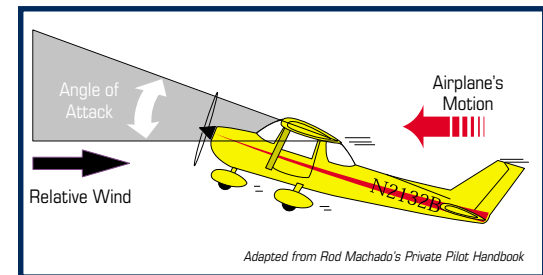


Figure 4-5 The Angle of Attack.

Figure 4-6 shows the wing (chord line) of Airplane A making a 5-degree angle to the relative wind. A more common way of saying this is that the wing's angle of attack is 5 degrees. Airplanes B, C, and D show increasing angles of attack of 10 degrees, 30 degrees, and 45 degrees, respectively. The greater the difference between the wing and the relative wind, the greater the angle of attack. And, as you're about to see, the wing's lift is directly associated with its angle of attack.

CLASS 4: SLOW FLIGHT

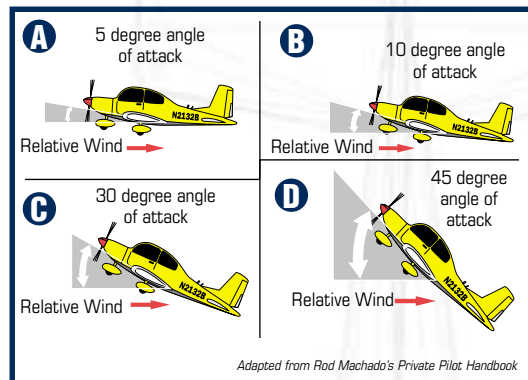


Figure 4-6 Angle of Attack. How Lift Develops

The wing is the ultimate air slicer. As powerful as any Ginzu knife, Samurai sword, or karate chop, it's a precision device for slicing air in a specific way. Wings are expressly built to plow through air molecules, separating them either above or below, while offering little resistance in the horizontal direction. Any horizontal resistance slows the wing down. This horizontal resistance is called drag, and it's definitely a case of less being better.

Figure 4-7 shows how the airfoil splits the wind when it's at a 10-degree angle of attack. Airflow strikes the leading edge

of the wing, forcing some air over and some under the airfoil (a fancy name for a wing). Both the air flowing over and the air flowing under the wing are responsible for generating lift. Let's first examine how the airflow striking the bottom of the wing produces some of the total lift that is developed.

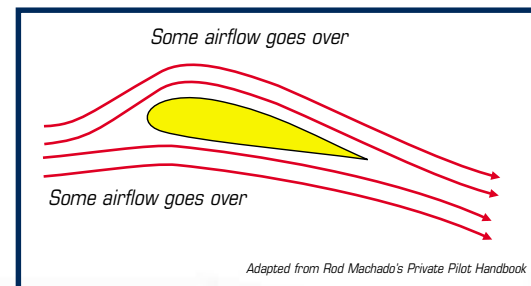


Figure 4-7. Airflow Over and Under A Wing. Lift from an airfoil is produced by air flowing over and under the wing.

Impact vs. Pressure Lift

Sticking your hand out the window of a moving automobile does two things: it demonstrates how a relatively flat surface develops lift, and it signals a left turn. Figure 4-8 shows that wind is deflected downward when it strikes your hand.

CLASS 4: SLOW FLIGHT

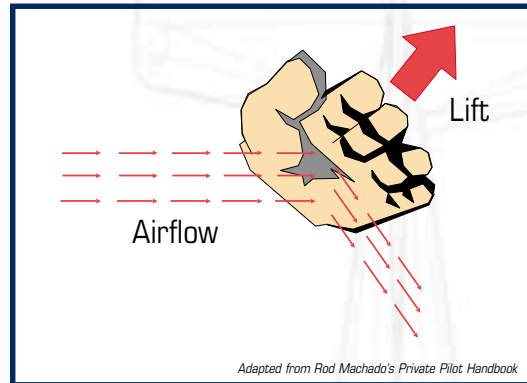


Figure 4-8 Impact Lift. Airflow striking the hand is deflected downward. This imparts an equal and opposite upward force to the hand. High pressure is created on the bottom of the hand by impacting air molecules.

According to Sir Isaac Newton, who knew about such things, for every action there is an equal and opposite reaction. Wind deflected downward by the airfoil creates an upward (opposite) movement of the wing. This upward movement is caused by the impact energy of billions of tiny air molecules striking the underside of the wing. Also, higher pressure on the bottom surface of the wing results from this molecular impact. The wing moves upward as if it were being pushed from below.

This type of lift is known as barn door, or impact, lift. It generally contributes only a small portion of the total lift produced by the wings, which means that man and woman do not fly by barn-door lift alone. If we could, it would mean people in the Midwest would report flying barn doors instead of UFOs.

A more subtle and powerful form of lift occurs from curved airflow over the top of the wing.

Bending the Wind with the Wing

The Japanese invented the art of paper bending and called it origami. They then experimented with people-bending and called it judo. This art was not perfected, however, until the airlines adopted the practice, which is referred to as “flying coach.”

Airliners (indeed all airplanes) bend something else—they use their wings to bend the wind. Wind bending did not sound sophisticated enough to explain why airplanes fly, so it was given a fancy Greek title. We call wind bending aerodynamics. Simply stated, the wing is a precision device for bending or curving the wind downward.

CLASS 4: SLOW FLIGHT

But how does bending the wind over the wing create lift? Let's find out.

Figure 4-9 shows a cross section of an airfoil. Examine its shape carefully. At small angles of attack, air flowing above the wing is bent, or curved, with great precision as it follows the upper cambered surface. A rather straight surface on the bottom of the wing leaves the air underneath relatively unbent. Bending, or curving, the wind above the wing forces air to travel a greater distance than the straighter airflow below. If the wind above is to reach the trailing edge at nearly the same time as the wind below (science and experiments say that it does), it must speed up to cover the greater distance.

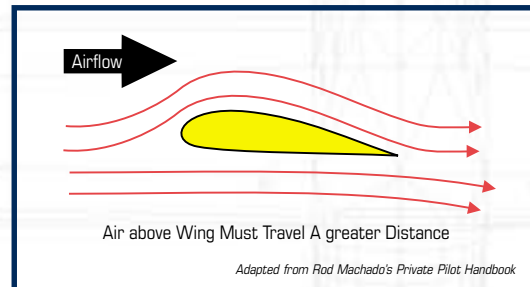


Figure 4-9 Airflow Above and Below the Wing at a Small Angle of Attack. At low angles of attack, the air above the wing is curved while the air below the wing is relatively straight.

For example, assume you are walking your pit bull (named Bob) on a leash. You are on the sidewalk, and Bob is walking in the gutter (Figure 4-10). Bob encounters a parked VW and decides to walk over the car rather than around it (remember, it's a pit bull). Obviously, the distance over the car is greater than the distance you will travel on the sidewalk. In order for Bob to avoid being choked by the leash, he will have to speed up slightly as he covers this greater distance.

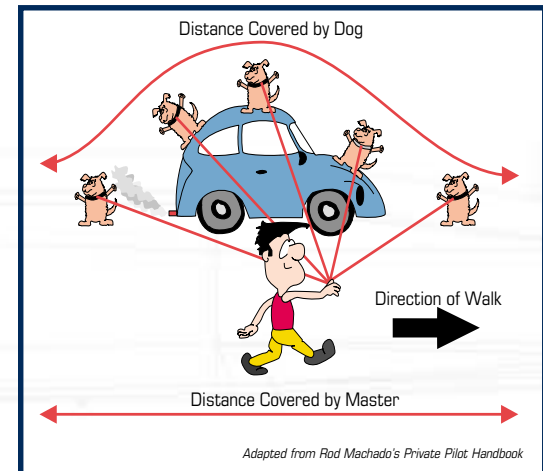


Figure 4-10 Different Distances in Curvature Above Than Below The Car (Wing too).

CLASS 4: SLOW FLIGHT

Do you notice the resemblance of the VW's profile to a wing? It's curved on top and rather straight on the bottom. As air flows over the wing, it curves and speeds up.

Something remarkable happens when air flowing over a surface increases its speed. A physicist named Bernoulli (pronounced BRR-NEW-LEE) figured out that the faster air flows over a surface, the less pressure it exerts on that surface. High-velocity airflow over the wing causes a slight decrease in pressure on the wing's upper surface. In other words, the pressure on top of the wing is now less than the pressure on the bottom of the wing (Don't ask why. It has to do with translational kinetic energy, and explaining that will give you something that feels like a two-scoop lobotomy). Known as Bernoulli's principle, this wonderful trick is what keeps airplanes from being large and expensive doorstops.

Most wings are designed with their upper surface curved and their lower surface relatively straight. Because of the wing's shape, even at a small angle of attack, a cambered wing still adds a slight curve and acceleration to the

wind. This produces the lift you learn to love, particularly if you think an airplane should fly.

Angle of Attack and the Generation of Lift

During takeoff on a commercial airliner, have you ever noticed that the pilot always raises the nose slightly to begin the climb after attaining a minimum forward speed? This is called rotation, and it isn't something that's done to the airplane's tires.

As the airplane accelerates for takeoff, it eventually reaches a sufficient speed to begin flying. At this relatively slow speed, however, the wing's engineered curve isn't capable of curving, or deflecting, enough air downward to produce the necessary lift for flight. This is why the airplane doesn't hop off the ground like a grasshopper that just landed on a hot barbecue. The pilot must do something extra to add an additional curve to the wind. Raising the nose slightly increases the angle of attack. This forces the air to undergo an additional curve greater than that which the engineered shape of the airfoil can produce. Figure 4-11 depicts this process.

CLASS 4: SLOW FLIGHT

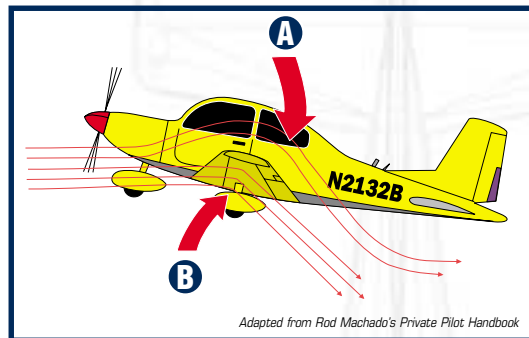


Figure 4-11 Two Forms of Lift. No. A—Lift from low pressure. At large angles of attack, the airflow is forced to curve beyond the engineered shape of the wing. No. B—Impact lift on the bottom of the wing increases at a high angle of attack.

With this additional curvature, air travels a greater distance, its speed increases, pressure lowers on top of the airfoil, and sufficient lift to begin flying is produced at a slower airspeed (thanks for the lift, Bernoulli!). Greater impact lift results from increased exposure of the wing's lower surface to the relative wind. The result is that an increasing angle of attack permits the airplane to produce the necessary lift for flight at a slower airspeed.

Now you know how airfoils generate the required lift at slower airspeeds. You also know why airplanes taking off or landing at slower speeds seem to have a rather nose-high attitude. But what happens at higher airspeeds? Have you noticed that in cruise flight at cruise airspeeds, airplanes fly at near-level flight attitudes?

Figure 4-12 shows an airplane at several different angles of attack. At higher speeds, airplanes can fly at lower angles of attack because the wing's shape generates sufficient lift. Slow the airplane, and the wing must artificially bend the wind by increasing its angle of attack.

CLASS 4: SLOW FLIGHT

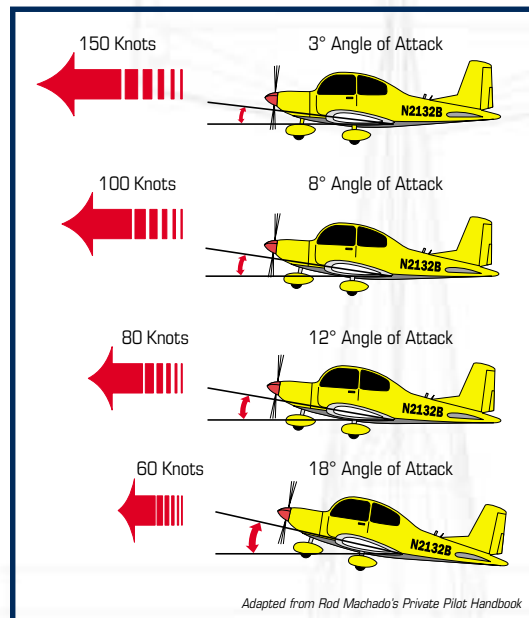


Figure 4-12 Relationship Between Angle of Attack and Speed. With speed variations in level flight, the relationship between the angle of attack and airspeed is clearly shown. With increasing airspeed, the airplane requires a smaller angle of attack to remain airborne. As the airplane's airspeed decreases, a larger angle of attack is necessary.

An intimate and sizzling relationship exists between angle of attack and lift. If lift and angle of attack were Rhett and Scarlett, Atlanta wouldn't be the only thing on fire. At small angles of attack

(such as during cruise flight), the engineered shape of the airfoil generates sufficient lift for flight as long the airspeed is high. The impact of air underneath the wing doesn't play as big a role in lift development at higher (cruise) speeds because less of the wing's underside is exposed to the wind.

In summary, the slower an airplane moves, the greater the angle of attack needed for flight. There is, however, such a thing as too much of a good thing. Bend the air too much, and instead of flowing smoothly over the wing and creating lift, it bubbles and burbles and pretty much fails to be uplifting. We call this condition a stall, and this will be covered in a future class.

Now it's time to talk about the details of entering and leaving slow flight as it's done in the air.

Slow Flight in Action

In straight-and-level flight at cruise power, the airplane moves through the air at approximately 110 knots. Our pitch attitude at this airspeed is approximately 4 degrees nose up, as seen on the attitude indicator. From this condition, let's discuss how you'll enter slow flight.

CLASS 4: SLOW FLIGHT

Let's make this realistic by supposing that you're preparing to land and must slow the airplane to 75 knots to keep from weed-whacking the airplane ahead of you. Here's the general procedure you should use for entering slow flight while maintaining altitude:

1. Reduce power to flight idle (with experience, you'll eventually learn the power settings for the speed you want and will reduce power to that value).
2. Raise the nose just fast enough to keep the VSI needle steady at zero (or the altimeter's hundred-foot hand steady).
3. As the airplane decelerates, apply a little nose-up trim to help maintain the nose-up pitch attitude (this is approximately 9 degrees nose-up pitch, as shown on the attitude indicator).
4. When the airplane is at the desired airspeed, apply enough power to hold your altitude (around 1900 RPM). Use small adjustments in pitch to maintain the desired airspeed.
5. Make a final trim adjustment (if necessary) to maintain the pitch attitude, which gives you the desired airspeed.

Leaving Slow Flight

Let's suppose we're following an airplane and the tower controller wants you to increase your speed from 75 to 85 knots. How do you accomplish this? Simply reverse the process used to enter slow flight:

1. Increase power a bit, say to around 2000 RPM.
2. Lower the nose just fast enough to keep the VSI needle steady at zero (or the altimeter's hundred-foot hand steady).
3. As the airplane accelerates, apply a little nose-down trim to help maintain the desired pitch attitude (which is approximately 6 degrees nose-up pitch, as shown on the attitude indicator).
4. When the airplane is at the desired airspeed, apply enough power to hold your altitude. Use adjustments in pitch to maintain this airspeed.

CLASS 4: SLOW FLIGHT

5. Make a final trim adjustment (if necessary) to maintain the pitch attitude, which gives you the airspeed you want (85 knots in this instance).

Here's What You've Learned

So far, you've examined how to fly the airplane at several different speeds. At this stage of your training, you should be aware that the throttle is best used to maintain your altitude or rate of descent. The airspeed is maintained by adjusting the airplane's pitch attitude. But what about when you're not trying to maintain a specific speed, such as in cruise flight? After all, in cruise flight, you don't maintain your altitude using throttle adjustments, do you? No, you don't. Here's why.

In cruise flight, you typically set the throttle to a power setting that won't harm the engine (for simplicity in teaching, we'll assume that the application of full throttle in any of our simulations won't hurt the engine). Then, for the most part, you leave the throttle alone. You're not necessarily concerned with maintaining a specific airspeed in cruise flight. In this case, power is fixed at a specific

setting, and you make slight adjustments in pitch attitude to hold or modify your altitude. In slow flight, however, you'll use power to control your altitude and pitch (joystick) to control your airspeed. This might be the opposite of what you'd guess. As you'll soon see, however, this is the technique I want you to use when landing an airplane.

You're On Your Own

Now I want you to proceed to Interactive Lesson Four and practice slow flight in the airplane. Your ultimate objective is to maintain altitude and heading while trying to fly at various slow flight-speeds of your choosing. At first, you'll find it a bit tricky to maintain airspeed and altitude while flying a precise heading. So establish your priorities as follows: First, adjust pitch to give you the airspeed you want. Then, while maintaining that pitch attitude, make small adjustments in power to hold your altitude.

If you feel lucky, try slow flight in turns. But be careful in those turns. Remember from the ground school class on turns that a slight increase in pitch attitude

CLASS 4: SLOW FLIGHT

was necessary to maintain altitude in a turn. Now that you know how to use the throttle, you'll want to add a little bit of power, if necessary, to help maintain altitude in a turn. The steeper the turn, the more power you'll need. Be generous with your use of trim in slow flight (although it's best not to trim in turns since turns are transient conditions). This prevents the airplane slinking away from the pitch attitude you want if your attention is diverted from the instrument panel. Above all, have fun!

CLASS 5: TAKEOFFS

Years ago, a fellow flight instructor had a student who spent a few too many hours on the high seas. On his first flight lesson, he walked out to the airplane, loosened all three tie-down ropes, tossed them aside, and yelled, “Castoff!” Hmmm, apparently, he still had a little sea water on the brain.

Sorry, but airplanes don’t do castoffs; they do takeoffs. And once you’re in the air, you need a practical way to return to an airport in preparation for landing. It’s similar to bringing a boat in to dock. You don’t just barge into the herd of boats heading for port. You get in line and follow the other boaters and fishermen back home. This way, they don’t get upset, which can lead to *fishticuffs*. And that will put the fear of *cod* in you.

Let’s start with the takeoff.

On takeoff, your objective is to accelerate the airplane to a sufficient speed where you can raise the nose to climb attitude. This is sometimes known as rotating. I recommend rotating at least 5 knots above the airplane’s no-flap stalling speed

(which is 50 knots—the beginning of the airspeed indicator’s green arc). When the airspeed indicator shows 55 knots, raise the nose to the attitude that results in an 80-knot climb (you’ll learn what this attitude is from experience. In this case, it’s 11 degrees nose-up pitch). Ready? Here’s how to do it.

First, apply full power and accelerate down the runway centerline. If you’re using rudder pedals and don’t have the autorudder feature active, then you should expect the airplane to yaw to the left when power is added. This happens for several reasons. Things like the propeller slipstream and engine torque all contrive to make this airplane turn left during takeoff. Just add enough right rudder to keep the airplane aligned with the runway. Of course, if you don’t have rudder pedals, don’t worry about the airplane tending to turn left on takeoff. The airplane’s auto-rudder feature will prevent these forces from affecting you.

When the airspeed indicator shows 55 knots, the airplane’s ready to fly. So fly. Rotate the nose to an 11-degree positive

CLASS 5: TAKEOFFS

pitch, as shown in Figure 5-1. (It takes a little extra initial back pressure on the joystick to unstick the airplane from the runway during rotation.) Be patient. The airplane will eventually accelerate to 80 knots at this attitude.



Figure 5-1

Congratulations! You've just taken off. Not too tough, eh? Now it's time to proceed to the Interactive Lesson on takeoffs and practice what you've just learned.

Of course, what goes up must eventually come down. And when it does, it better be able to land properly. That's why our next class will cover landings.

CLASS 6: LANDINGS

There's a saying that every pilot knows, and since you're going to be a pilot, you should know it, too: Takeoffs are optional; landings are mandatory.

Landings are to a pilot what a beautiful painting is to an artist. When you look at Da Vinci's Mona Lisa (or its famed counterpart, the Mona Larry), you see a beautiful work of art. To pilots, a good landing offers the same satisfaction. I intend to show you how to paint that beautiful picture on any runway of your choice.

We're going to approach this class a little differently than I would in the actual airplane. I plan on teaching you how to land before teaching you about flying the traffic pattern (which will be covered in the private pilot curriculum). That way, when I teach you to take off and fly a traffic pattern, you can actually land, instead of dropping to earth with all the grace of a butterfly that's overdosed on caffeine. Besides, something tells me that if we don't do landings now, you'll be out there practicing them yourself. So let me help you put your hand in the cookie jar.

I always tell my students that airplanes will land themselves (well, almost). All the pilot has to do is nudge the plane toward the runway and twiddle the throttle a bit. Let's examine how this is done by landing an airplane in your brain, or, to put it another way, by using your imagination to make your first landing.

Your First (Mental) Landing

For this visualized example, I want you to imagine that you're lined up with a long runway. Visualize yourself at 500 feet above the ground while approaching at a speed of 65 knots. The power is set to idle. Mentally adjust the pitch to maintain 65 knots. This will require about a 10-degree nose-up pitch, as shown in Figure 6-1. Of course, you should also imagine trimming the airplane to maintain 65 knots. Now for the best part of this example. Imagine flying 65 knots at this pitch attitude all the way to touchdown with the power set to idle. What do you think will happen?

CLASS 6: LANDINGS



Figure 6-1

If you said that the airplane will land, you're correct. In fact, as long as you maintain an airspeed of 65 knots, the airplane will almost land itself. Of course, if there is any carbon on the runway, you'll convert it to diamonds, perhaps sending a few groundhogs six feet under in the process. Despite the impact, this is nearly what a landing is like. The only difference between what you imagined and what makes a good landing is something called the landing flare.

The fact is that we don't fly airplanes into the ground. We flare them just before we land. No, a flare isn't a lighted stick you

throw out the window to let others know you're landing. It's a maneuver that involves changing the descent path to shallow the airplane's approach to the runway. The flare is begun during the last 10-15 feet above the ground. We'll talk about this in a bit. For now, you should understand that the secret to making good landings is letting the airplane do most of the work. In other words, if the airplane is trimmed for the proper airspeed, there's little else to do other than keep the wings level and make small adjustments in power to vary the glidepath. The airplane will almost land itself if you keep it aligned with the runway.

Now for the details.

Landing Details

Why did I choose 65 knots as the speed to fly the final approach? (Final approach is the portion of the landing pattern where the airplane is lined up with the runway.) Pilots typically use a final approach speed that is 30 percent above the airplane's stall speed. In our case, the airplane's no-flap stalling speed is 50 knots (this is where the green arc begins on the airspeed indicator). Thus, our +30 percent speed is 65 knots. Fly a little

CLASS 6: LANDINGS

faster than that, and the airplane will tend to float and resist touching down on the landing spot you want (approaching too fast is one of the biggest mistakes new pilots face while learning to land). Fly a little slower, however, and you'll place the airplane uncomfortably close to its stall speed. Controlling your airspeed is perhaps the most important quality for a successful landing.

For our airplane, 65 knots keeps the nose gear just a little higher in relation to the main gear, as shown in Figure 6-2. Remember, as the airplane slows down, the angle of attack must increase to maintain lift. Therefore, an approach speed of 65 knots requires a slightly larger angle of attack. Thus, the nose gear raises relative to the main gear. Keep in mind that the Cessna 172 is a tricycle-gear airplane. It's designed to be landed on the two main gear wheels first, after which the nose gear is gently lowered to the ground. Land on the nose gear first, and you could invoke the scariest phrase in a pilot's vocabulary: insurance deductible. You could also porpoise, which is a bouncing action, not a tuna's playmate.



Figure 6-2

Playing with Power

Let's say you've trimmed the airplane for a power-off descent at 65 knots. As you approach the runway, you discover that your approach path will take you to a point short of the runway. This isn't a good thing. After all, airplanes are supposed to land on runways, not in the farmer's field short of the runway. How can you tell if you're going to land short in the first place and what you should do to correct this problem?

CLASS 6: LANDINGS

You can tell that you're descending too quickly when you observe the runway geometry changing, as shown in Figure 6-3. View A is what the runway should look like over the panel when you're on an acceptable glidepath. View B is what the runway looks like when you're too low (below the desired glidepath). View C is what you'll see when you're too high (above the desired glidepath).



Figure 6-3A



Figure 6-3B



Figure 6-3C

CLASS 6: LANDINGS

Notice that the distance between the far end of the runway and the distant horizon decreases in View B. Also notice that both ends of the runway appear to converge. Both of these are good visual cues that you're below a desired glidepath. Finally, you know you're too low when desert shrubbery appears at eye level and you skid your tires on a desert tortoise.

Without using any mechanical or electronic aids, it does take some practice and experience to tell when you're on the correct glidepath to the runway. At some airports, there are devices that can help you determine the proper glidepath for a particular runway. Take a look at the sidebar on VASIs to learn more about these. When you first begin the Interactive Lesson on landings, it's okay to rely on your gut feeling about whether or not you're high or low on approach. This will train your visceral senses. If you hear the wheels squeak before reaching the runway, you know you're too low. If you see the runway disappear underneath the airplane, you know you're too high. It doesn't get any more basic than that. After you gain just a little experience, you'll get better and better at selecting the proper glidepath, trust me, after all, I'm your flight instructor.

Visual Approach Slope Indicator (VASI)

Under poor visibility conditions or at night, the lack of outside visual clues sometimes makes determination of the proper landing glidepath difficult. Fortunately, there is something known as a Visual Approach Slope Indicator (VASI) that provides you with a visual clue as to the proper glidepath to fly. (By the way, VASI is pronounced VAZ-eee. It is not something in which you put flowers).

A VASI usually consists of two pairs of lightbars along the side of the runway (it's often called a two-bar VASI for this reason). The two VASI bars are usually 500 to 1,000 feet from the approach threshold, as shown in Figure 6-13. These lights project either a red or white color, depending on your altitude. The colors are constant and don't actually change within the box. What it does change is your height, which allows you to look at the VASI from different angles and see different colors.

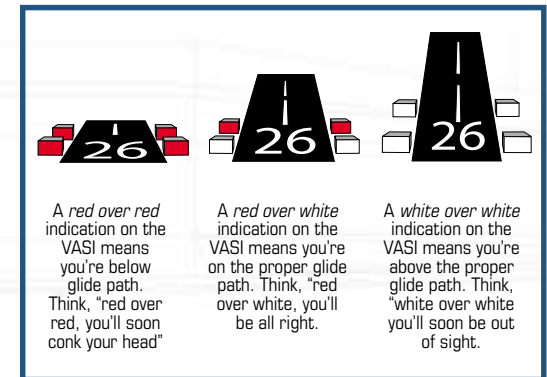


Figure 6-13. The 2-Bar VASI (Visual Approach Slope Indicator)

Adapted from Rod Machado's Private Pilot Handbook

CLASS 6: LANDINGS

Glidepath Adjustment If You're Too Low

Okay, let's suppose you know you're too low. How do you correct for this?

At the first indication of being too low, increase power. This is a no-brainer (although I want you to keep your brain because you're going to need it for the flare). You'll notice that your descent rate immediately decreased a little after adding power, as shown in Figure 6-4. Small power adjustments make small adjustments in glidepath. Use whatever power you need to get the airplane to the runway, all the while maintaining an approach speed of 65 knots. Ideally, your glidepath should take you straight to the runway without numerous vertical bends or curves in the airplane's trajectory. Ah, if this were only a perfect world, eh? It's not. Therefore, be willing to make any power adjustments to vary the glidepath as necessary to make it to the runway.

When you are below the proper glideslope, both VASI bars show red. Some pilots remember that this signals trouble by thinking of it as, "Red over red, you'll conk your head." You should level off until you see red over white. Red over white means that you're above the glidepath for the bar closest to you and below the glidepath for the bar farthest away. This is a complicated way of saying you're on the glidepath that will plunk you down halfway between the two bars. A good way to remember this is, "Red over white, you're all right." Of course, if you're too high, both bars will show white. A good memory aid for this is, "White over white, you'll soon be out of sight." Increase the descent rate until the upwind bar turns red. You can expect the VASI's red and white bars to transition through a pink color as your altitude in relation to the proper glideslope changes.

If you see flashing red over flashing white, then you're making an approach to a police car. Now you're in really big trouble (besides, it's not natural for the VASI bars to chase other cars down the highway).

CLASS 6: LANDINGS



Figure 6-4 A-VSI and B-tachometer with slightly more power. C-VSI and D-tachometer with slightly less power

On the other hand, if you're way too low, it's perfectly reasonable to add power and hold your altitude until you're in a position for a normal glide to the runway. Once again, experience will tell you when you're in a position to reduce power and begin a normal glide to the runway. Of course, if you've misjudged and are really low, you should start a climb. Then, when you're high enough for a normal glide to the runway, you simply reduce power and commence the descent. It may look like a

spaghetti approach, but it's your approach (however, you should be prepared for an al dente landing). Do whatever it takes to get to that runway. Make sure you use your trim during this process, too.

What do you do if you're too high? We'll cover that shortly. For now, let's look at how to flare the airplane for landing.

The Landing Flare

Until now, you've mentally flown the airplane onto the runway at a final approach speed of 65 knots. You might be able to get away with this in a real airplane, but only in an emergency. At 65 knots, the simulated airplane is in a minimally acceptable landing attitude (that is, the airplane is pitched nose-up, putting the nose gear slightly above the main gear. This is a good thing). Additionally, the descent rate in this simulation isn't so excessive that the landing will bruise everyone's bones, although it's still possible to sustain some damage to a real airplane during landing. Therefore, to land properly under all conditions, you must learn to flare the airplane to ensure a soft, safe touchdown.

CLASS 6: LANDINGS



Figure 6-5

You should begin the landing flare at approximately 10 to 15 feet above the runway, as shown in Figure 6-5. While descending at the desired approach speed, start the flare by raising the nose with a slight and gentle pull on the joystick. How much of a pull? Once again, that's a matter of experience. The objective is to lower your descent angle and decrease the airspeed for landing. Now the airplane can settle onto the runway at a smaller descent rate and at a slightly higher nose-up attitude. This makes for a softer touchdown and keeps the nose gear higher than the main gear, as shown in Figure 6-6.



Figure 6-6

If your speed is too high on the approach (that is, faster than 30 percent above the airplane's stall speed), it's likely that you'll float or possibly begin to climb during the flare. This is not a good time for this to happen. Floating means the airplane just won't land. Unless you have a long runway, this may mean that you'll turn an expensive airplane into an off-road vehicle as you bust through the fence surrounding the airport. If you pull back too quickly during the flare, you may find yourself 50 to 100 feet above the runway while out of airspeed and ideas at the same time.

CLASS 6: LANDINGS

In this instance, you'll need to add power, lower the nose a bit, and descend to a point where you can flare again. If you don't do this, the airplane might stall. Excuse me for saying this, but practicing stalls at 100 feet above the ground is definitely a ground-breaking idea. (Ouch! Deductible!) The only time it's legitimate for the airplane to stall during the flare is when it does so a few inches above the ground. This way, it only has inches to fall, which hurts neither the airplane nor those on board. Yes, the flare requires a little timing, but there's a lot of latitude in how it's accomplished.

How can you tell when you're at a flare height of 10-15 feet? In a real airplane, you have peripheral vision to help. In the normal cockpit view of the simulator, you can't use any cues from the side windows because you don't have side windows. (You could try the Virtual Cockpit view, which allows you to pan around in any direction using the hat switch on top of your joystick. Try it! On the **View** menu, select **View Options**, and then choose **Virtual Cockpit**.)

With practice, even in the normal cockpit view, you'll develop your ability to determine your height above the runway. In the meantime, you can use the altitude of the runway (or airport elevation) as an aid. Suppose, for instance, that the airport's elevation is 2,787 feet above sea level. You can begin your flare when the altimeter reads 2,800 feet. Of course, this is only a helpful hint when learning to land in a simulator. You shouldn't be doing this when you become a pilot and are landing a real airplane. It will make your copilot nervous.

There is one more nifty idea that can help you land smoothly if you're having a hard time identifying when to flare. When you even think you're getting close to flare height, add just enough power to slow the descent rate to 100 feet per minute while maintaining your approach speed, as shown in Figure 6-7. This is close to how seaplane pilots make approaches to glassy lakes that have no ripples on them. It's difficult to judge your height above a lake that reflects like a mirror. Maintaining a 100-foot-per-minute

CLASS 6: LANDINGS

descent rate at the approach speed will allow the airplane to make an acceptable touchdown (and avoid conking a trout on its head). Doing this on a runway means that your landing distance will be longer because of the addition of power, so be sure to have a long enough runway.



Figure 6-7

Under normal conditions, you should gradually reduce power to idle when you begin the flare. Then, you should gently raise the nose to flare attitude and allow the airplane to settle onto the runway at this attitude. If you need a better idea of how high to raise the nose, trying raising it to a 14-degree pitch attitude on the

attitude indicator. At this attitude, the airplane will settle onto the runway. As the airplane continues to slow down, you'll need to increase back pressure on the joystick to maintain the desired nose-up flare attitude. Once you've touched down, gently release any joystick pressure to lower the nose gear onto the runway (in airplanes, the nose gear provides directional control after landing).

It's also not unusual to lose sight of the runway over the panel as you begin the flare. In a real airplane, you could jack the seat up to get a better view. No, the instructor isn't going to put you on his or her lap to give you a better view. In the simulator, you have neither a jack nor an instructor to give you a boost. Raise the simulator's seat electronically by pushing **SHIFT+ENTER**. Don't worry, this isn't an ejection seat. Raise the seat as high as you need to get the best view. To lower the seat, press **SHIFT+BACKSPACE**.

Wonderful! You have a flair for the flare. Of course, there's something of an art to perfecting this, but you'll eventually master it with practice. Now that you understand the flare, let's discuss how to do it with full flaps. When do we use flaps? When the airplane is too high and

CLASS 6: LANDINGS

we need to increase our rate and angle of descent. Let's discuss flaps in detail before we discuss how to land an airplane using them.

Flap over Flaps

Ever wondered why the wings of large commercial airplanes sprout aluminum prior to takeoff and landing? Fast airplanes require small, thin wings to achieve the eye-popping velocity needed to satisfy today's speed-hungry air traveler. The problem with thin, small wings is that they stall at high speeds. Most jet airliners would have to take off and land at close to 200 mph to achieve a safe margin above stall if they couldn't enlarge and curve their wing's surface area enough to create a temporary, low-speed wing. Engineers, however, design wings to do just that by supplying them with flaps. Extending or retracting flaps changes the wing's lift and drag characteristics.

Lowering flaps lowers the trailing edge of the wing, as shown in Figure 6-8. The wing's lift is increased in two ways. First, the lowered trailing edge increases the angle the chord line makes with the relative wind. Greater lift results from

this increased angle of attack. Second, the lowered trailing edge increases the curvature on part of the wing, resulting in increased air velocity over the wing's upper surface (many flaps even increase the wing's surface area by extending downward and outward, as the Cessna 172 does). Because of the larger angle of attack and greater curvature, flaps provide you with more lift for a given airspeed.

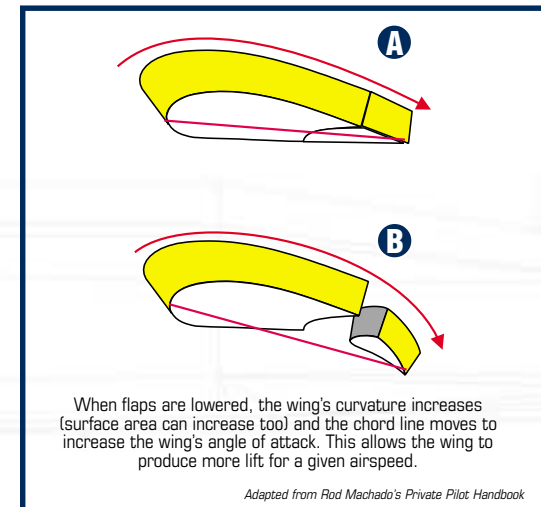


Figure 6-8 How flaps change the wing's curvature. A-Wings Slightly Curved, flaps up. B-Wing Curved More.

CLASS 6: LANDINGS

What's the reason for putting flaps on small airplanes? First and foremost, they create the lift necessary to maintain flight at slower airspeeds. When landing, your goal is to approach and touch down at a reasonably slow speed. You certainly don't want to touch down at cruise speed. Such a high-speed landing might just turn your tires into three little puffs of smoke. Flaps allow you to approach and land at a slower speed while maintaining a safe margin above the stall speed.

A slower speed on touchdown means less runway is used to stop. This is an important consideration if the runway is short. Alternatively, if the wind is gusty, you might consider approaching with little or no flap extension. At the slower speeds allowed by flaps, the airplane becomes more difficult to control because the controls are not as responsive. Let's see how effectively the flaps increase lift by referring to the airspeed indicator (Figure 6-9).

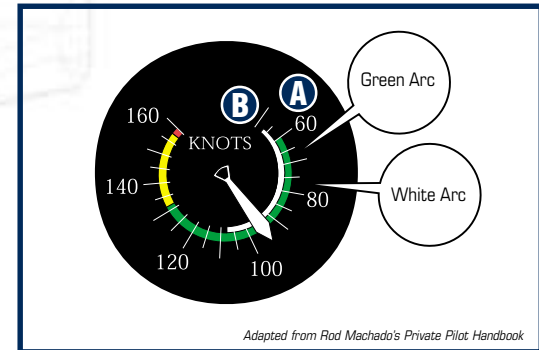


Figure 6-9 Flap Speed Range. A-Flaps extended - 53 kts. (beginning of white arc). B-No flaps - 60 kts. (beginning of green arc)

Since the flaps on our Cessna 172 are painted white (we'll assume they are for this discussion), the airspeed indicator's white arc represents the flap operating range. The beginning of the white arc (B) is known as the power-off, full-flap stalling speed (in nonaccelerated flight at the airplane's maximum allowable weight). It's the speed at which the airplane stalls with flaps fully extended, power off, and the gear extended. In Figure 6-9, the airplane will fly when 53 knots of wind blows over the wings if they are below their critical angle of attack.

CLASS 6: LANDINGS

The high-speed end of the white arc is the maximum speed you can fly with flaps fully extended. Flying beyond this speed can damage the flaps. In this example, you wouldn't want the airspeed indicator to indicate more than 107 knots with flaps extended (some airplanes, however, allow you to fly at a higher speed with partial flaps extended). Bringing broken or bent airplanes back from a flight isn't a good idea, even if they are rentals (you'll find out how bad an idea it is when you get the bill for unbending the metal).

Notice that the white arc (B) begins at a speed seven knots slower than the green arc (A). In an earlier discussion, we learned that the green arc is the power-off stalling speed with flaps retracted (gear retracted, too). This airplane must have 60 knots or more of wind flowing over the wings to fly with flaps retracted. With flaps fully extended, you can touch down at a slower speed—seven knots slower, to be exact (the full-flap stall speed on the airspeed indicator assumes the airplane is at its maximum allowable weight).

But, as Confucius might say, “Man who sow ‘wild oats’ eventually have crop failure.” In other words, you don't get

something for nothing. Flaps provide you with lift, but they also produce drag. Full flaps create a low-speed wing. Try to accelerate it, and at some point, drag defeats your efforts. Fortunately, the first half of flap travel usually provides more lift than drag. The last half usually provides more drag than lift. This is why some aircraft manuals recommend only 10 to 25 degrees of flaps for takeoffs on short fields (usually one or two notches on a three- to four-notch, manual flap system).

If you're too high while on approach to land, you can select full flaps to increase the airplane's drag. It's common to use flaps only when descending within the traffic pattern and not when descending from cruise flight. After all, cruise flight descents are efficient and fast at higher speeds, where the parasite drag is greater. If you wanted to descend with flaps from cruise flight, you'd have to slow the airplane down below maximum flap-extension speed (the top of the white arc) before applying flaps. This would be cumbersome. The airplane can descend faster at cruise speed with reduced power while getting you to your destination sooner.

CLASS 6: LANDINGS

Since flaps provide more lift at slower speeds, think carefully about how and when they are retracted while airborne. If you're making a full-flap approach and it's necessary to go around (that is, give up this approach, climb, and return for another landing attempt), don't retract the flaps all at once! This would be like having someone remove a part of your wing at a slow speed. The sudden and often dramatic increase in stall speed could place you near a stall before you can accelerate to a safer speed. Apply full power first, and then retract the flaps in increments. In airplanes with 30 to 40 degrees of flap extension, retract the flaps to their least-drag/maximum-lift position. Usually, this position is found at one-half flap travel (depending on the airplane). In airplanes with three notches of manually applied flaps, retract one notch first, followed by the other two, once the airplane begins to accelerate.

Landing using Flaps

You can apply flaps using the flap handle (Figure 6-10) or by pressing the **F7** key on your keyboard (you can retract them by pressing the **F6** key).



Figure 6-10

Since flaps alter the lift and drag characteristics of the wing, be ready to adjust the pitch to maintain the airspeed you want. Applying full flaps creates a lot of drag. Flap application also causes the airplane to pitch up, requiring forward pressure on the joystick to maintain your airspeed. Here's how the process might go if you're too high and need to add flaps to compensate.

Since the full-flap stalling speed for this airplane is 40 knots (that's where the white arc begins on the airspeed indicator), you'll want to approach at a slightly slower speed. Remember, pilots use an approach speed that's 30 percent above the stall speed for the airplane's present configuration. For this simulation, let's use 60 knots.

CLASS 6: LANDINGS

While approaching without flaps at 65 knots, let's assume we notice the runway is disappearing below the top of the airplane's panel (Figure 6-11). This is one cue that you're going to be too high on the approach. Now's the time to add flaps (or more flaps). On your keyboard, you'll press **F7** once to lower 10 degrees of flaps. You'll also have to apply a little forward pressure to correct for a flap-induced pitch up, and then readjust the pitch for a final approach speed of 53 knots. Don't forget to trim!



Figure 6-11

You'll apply the other 20 degrees of flaps in 10-degree increments by pressing **F7** two more times until 30 degrees of flaps are extended (that's full flaps for this airplane). As you press **F7**, make sure you adjust the pitch for 60 knots of airspeed.

If flap usage is sufficient, you'll notice that the runway stops disappearing underneath the airplane. The airplane has also pitched forward a bit, allowing a better runway view. The descent rate will also be increased, and the airplane will fly at slightly less of a nose-up pitch as a result of flap application, as shown in Figure 6-12 (that is, with flap application, the nose gear isn't as far above the main gear — an additional reason for the flare).

CLASS 6: LANDINGS



Figure 6-12

One of the first things you're sure to notice while using flaps is that the rate of descent is higher. That's why the flare needs to happen a little faster when using flaps. When you're at flare height, raise the nose from its present attitude to about 14 degrees nose-up pitch. Hold that attitude until touchdown. Yes, you may hear the stall horn (more on this in the stall section) as you touch down, but that's okay since you're just inches above the ground.

So why use flaps? They allow you to touch down at slower speeds, which means less energy needs to be dissipated when stopping. Additionally, flaps

Solos and Shirttails

No one knows the origin, exactly, of when it became the custom to cut the shirttail off a fledgling student pilot, but it's a tradition that's still practiced by thousands of instructors on the occasion of the student's first solo flight. Some say it's from the old days of open tandem cockpits, where the instructor sat in the rear seat and the student sat in the front seat. To get the student's attention, the instructor would lean forward and tug on the student's shirttail. Solo flight = no instructor; hence, no need for shirttail tugging.

I don't know the origins, exactly, but it's a fun custom, and there's nothing that brings more pride to me as an instructor than when I'm watching a student pilot take to the skies alone for the first time.

Now, it's your turn to solo. Get out there, do me proud, and then press the Print key at the end of your flight. You'll get a cool little replica of a torn shirttail commemorating this exciting event.

come in handy when you're too high on approach. They are also useful when landing over an obstacle or when landing on a short runway.

This will complete our basic Student Pilot Classes. You're going to solo! Now you're ready to move onto the Private Pilot Lesson Sequence. So be prepared to wander the skies alone in search of new adventures.

CLASS 7: TAXIING THE AIRCRAFT

"Before you can learn to run, you must learn to walk." That's what my grandfather always told me. He also told me that I was adopted. When I sighed in disbelief, he said, "Yeah, that's right, adopted, but they brought you back. Ha!" There's my grandfather's sense of humor for you.

If my grandfather was a flight instructor (he's not), I'm sure he would have said, "Before you can learn to fly, you must learn to taxi." He would have been right, too. Here are a few taxi tips you should be familiar with before you go charging off into the wild blue yonder.

Taxi Thoughts

Airplanes are often graceful birds in the air. On the ground, however, they're clumsy—kind of like an albatross. To put it simply, they aren't meant to spend a lot of time on the ground. Therefore, engineers don't design them with all the creature comforts you'd expect of a ground-bound vehicle. You shouldn't expect to find power steering in your Cessna 172, for instance. You will, however, find pedals on the floor of the cockpit in a real airplane. These are how you'll steer the airplane during taxi.

Taxiing is rather easy. If your simulator is equipped with rudder pedals, simply push one or the other to turn the airplane. (If you've got rudder action built into your joystick, just twist the joystick, and it will have the same effect as pedals.) Pushing a pedal deflects the airplane's nose gear in the same direction, causing the airplane to turn. For example, pushing the right pedal makes the airplane turn to the right. Once airborne, the airplane's nose gear extends into a position that prevents it from turning. When this occurs, pushing a rudder pedal deflects the rudder and not the nose gear.

If you don't have rudder pedals, then life is much simpler for you. You steer by deflecting the joystick. The airplane turns in the direction the stick is deflected. It doesn't get any easier than that.

A word of caution: You want to avoid taxiing fast. The faster you taxi, the easier it is to have the airplane do something you don't want it to do. Tricycle-gear airplanes, for example, are unstable when they have to stop quickly. Anyone who has ever ridden a child's tricycle knows this. One quick stop or too sharp a turn causes the tricycle to topple over.

CLASS 7: TAXIING THE AIRCRAFT

It's the same with airplanes. As a general rule, you don't want to taxi faster than you can walk. Of course, if everyone walked with the stride of Wilt Chamberlain, the pilots would have more patience during taxiing. Try to taxi slowly.

You do this by using only enough power to start the airplane moving and then reducing it to about 1000 RPM. If the airplane starts moving too quickly, then reduce the power to idle and apply the brakes. Slow the airplane down to an acceptable taxi speed, and continue as before.

Taxiing the airplane is the easy part of this process. The difficult part is figuring out how to get where you want to go on the airport. You can't just head out across the airport unless you know something about taxiway and runway markings. If you're at an airport with an operating control tower, then you need to contact ground control for permission to taxi.

Airport Markings

Have you ever wondered what all those small trucks at airports—the ones with the flashing yellow lights—do? I thought I knew. For a long time, I was convinced they brought sandwiches to the student pilots who became lost on the airfield. After all, even students need sustenance while attempting to navigate from taxiway to runway to parking spot.

An airport's signage and markings are one situation in which consistency makes for confidence, and the FAA lends a helping airfoil by specifying in great detail how airport runways, taxiways, and other aircraft movement areas are to be laid out, marked, and lit. While it's not quite true that if you've seen one airport you've seen 'em all, there is a method to the apparent madness. Just like a Buck Rogers secret decoder ring, you have to decipher what's in front of you.

Let's take a look at Chino, California, shown in Figure 7-1. The airport is graced with two runways capable of

CLASS 7: TAXIING THE AIRCRAFT

handling takeoffs and landings in four different directions (two directions on each of the two runways, for the geographically challenged).

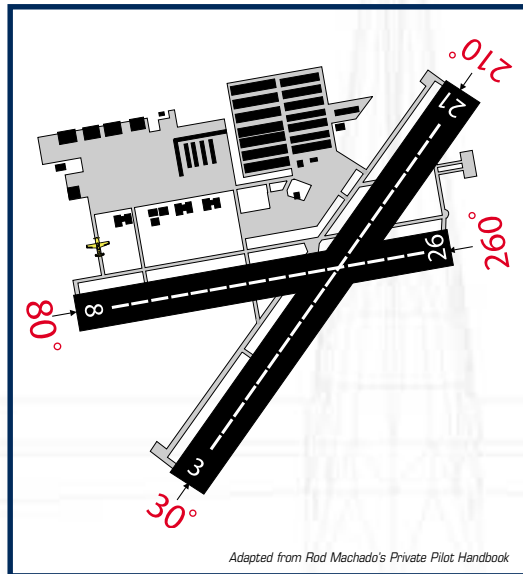


Figure 7-1 The airport layout for Chino.

Since Chino is a tower airport, and since controllers get upset when you land on a different runway from the one they had in mind, it's helpful to know that runways

come with numbers, which are always large and painted in white. Runway numbers and their markings help distinguish them from the airport's nonlanding surfaces. Chino's runways are numbered 8, 26, 21, and 3.

You think they just make those numbers up, don't you? I had a student who thought runway numbers were based on some sort of speed limit or seismograph record. Uh huh. The numbers represent the first two digits of the runway's actual three-digit magnetic direction. Essentially, a runway's numbers are its direction, rounded off to the nearest 10 degrees. A runway oriented at 211 degrees becomes Runway 21 (pronounced "runway two one" when speaking to controllers and other aviation-savvy people). A runway pointed 076 degrees becomes Runway 8 (rounding up).

There are two sides to almost every issue, and two ends to every runway. With rare exceptions (usually having to do with terrain), you can theoretically land or take off from either end. This means each piece of runway pavement has

CLASS 7: TAXIING THE AIRCRAFT

numbers on each end. Those who are way ahead of me will realize these numbers, when expressed as three-digit figures, differ by a value of 180. Makes sense, since the two directions are 180 degrees apart.

All runway angles are oriented to the magnetic North Pole, where the magnetic compass points, and not the true North Pole, where Santa Claus (a pilot) lives. When your airplane is pointed down any runway, the airplane's magnetic compass should approximately indicate that runway's direction. Figure 7-2 shows what the compass and the directional gyro might look like when aligned with Runway 26 at Chino. In Class 14, you'll learn more about magnetic and true direction. For now, just remember this when operating at an airport: wind direction, landing direction, and any headings ATC asks you to fly are all based on magnetic direction.

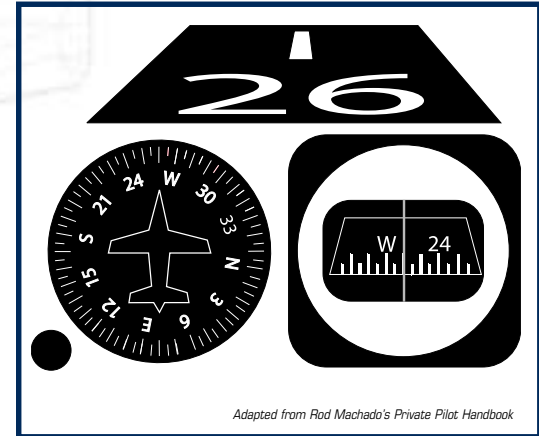


Figure 7-2 The runway's magnetic direction. Both the heading indicator and the magnetic compass show the magnetic direction when pointed down the center of runway 26.

Runway Lighting

Painted white, runway markings are easy to identify during the day, but what about at night? Don't look for Day-Glo™ orange any time soon. The airport has an image to maintain. Besides, the airport would become a magnet for rock stars and flower-painted VW buses if those colors were used.

CLASS 7: TAXIING THE AIRCRAFT

The answer at night is light. As the sun sinks slowly into the west, the airport often lights up like one of those amusement park parades. All kinds and colors of lights, some flashing and some steady, are there to amuse and confuse you. Think of it as color-coded hints, and you'll be on the right track.

White lights, shown in Figure 7-3, border both sides of the runway. Called runway edge lighting, these lights are spaced 200 feet apart. Controllers turn these lights on between sunset and sunrise or when visibility is poor.

The beginning of the runway is announced with green threshold lights, while the far end of the runway is lit in red. It's an appropriate color to indicate you are running out of usable landing surface (only tractors, bulldozers, and dune buggies beyond those red lights, please!). These lights actually lead a dual life. On one side they're green; on the other, red. Think about it for a second. The beginning (or threshold) of one runway is the end of another. The lights on the threshold of Runway 21 are also at the terminus of Runway 3.

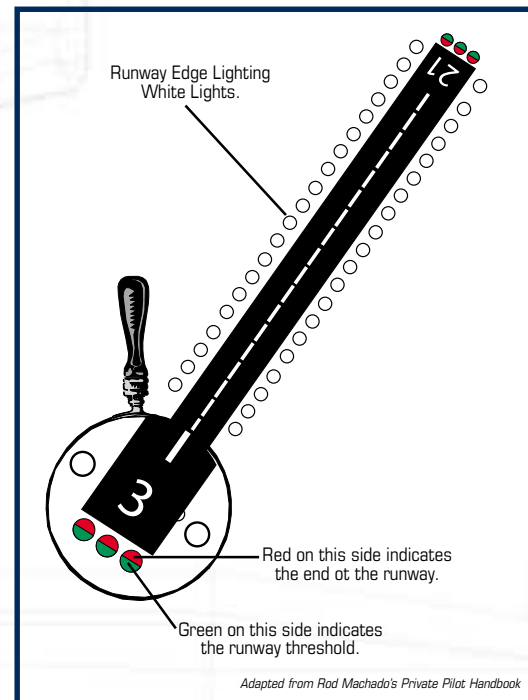


Figure 7-3 Basic runway lighting.

What I've described so far are the basics of runway lighting, which you will encounter at almost any airport that supports night operations. It can and does get a lot fancier. While gathering aviation

CLASS 7: TAXIING THE AIRCRAFT

experience, you're sure to come across airports with sophisticated lighting. In fact, airports with precision-instrument runways can have such detailed lighting that it's possible to mistake it for a prairie fire. Some runways have centerline lighting, with embedded lights running the entire length of the runway centerline. Some have brilliant, sequenced, flashing strobe lights leading to the runway threshold. Others have touchdown zone lighting, which looks like a gigantic Christmas tree was squished into the first 3,000 feet of the runway. One of my students said it was so pretty, he wasn't sure he should land on it. You can! See the *Aeronautical Information Manual* for additional information on these lighting systems.

Taxiway Markings

There are few things as pitiful as a pilot on the ground, even in the daytime. The King or Queen of the Airways can easily become the Lost Platoon when the gear hits the ground. It is a common misconception

that pilots are endowed with some superior ability to find their way around airports. This is demonstrably untrue. Most pilots can find a vending machine blindfolded, but many of us have trouble getting from the runway to the tiedown spot at an unfamiliar airport. Pilots and their airplanes have been extracted from some rather unusual places (like the time a fellow pilot accidentally taxied into a secret military hangar at a combo civilian/military airport. It obviously wasn't much of a secret, since they were in the habit of leaving their doors open.)

Figure 7-4 shows a drawing of taxiway markings from an airport chart. Taxiway D (Delta) parallels the north side of Runway 8-26, and Taxiway C (Charlie) parallels the northwest side of Runway 3-21. There are several intersecting taxiways with individual phonetic names.

At larger airports, and even at smaller ones when ground traffic or construction exists, it's not unusual for a tower controller to offer a complex taxi clearance.

CLASS 7: TAXIING THE AIRCRAFT

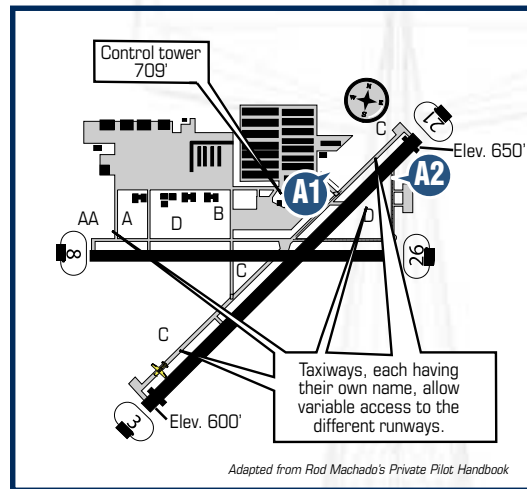


Figure 7-4 Taxiways at a typical airport.

Here's such a clearance: "November 2132 Bravo, taxi to Runway 21 via Charlie, southwest to Delta, turn left; cross Runway 21 and make a left turn on Golf, over." Students normally respond to this clearance with a, "Huh?" If you had an airport chart out, you could easily navigate from position A1 to position A2 in Figure 7-4 without getting lost. Many varieties of airport charts (similar to the one in Figure 7-4) are available to make airport-ground navigation easier.

Taxiways are identified by a continuous yellow line with parallel double yellow lines on the outer edges of the taxi surface (Figure 7-5). Taxiway names are shown on small signs.

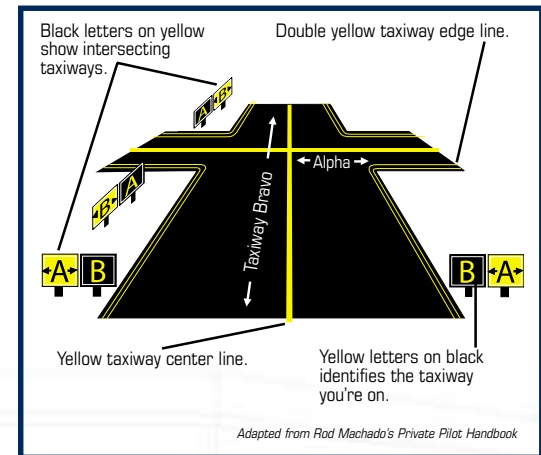


Figure 7-5 Taxiway Markings. All taxiway markings are in yellow.

Placed along the side of the taxiway, these signs consist of yellow lettering on a black background. Signs containing black lettering on a yellow background indicate the position of intersecting taxiways. Arrows indicate the relative direction of these intersecting taxiways.

CLASS 7: TAXIING THE AIRCRAFT

At night, many (not necessarily all) taxiways have blue omnidirectional side-line lighting (Figure 7-6). At some airports, taxiways may have embedded green centerline lighting.

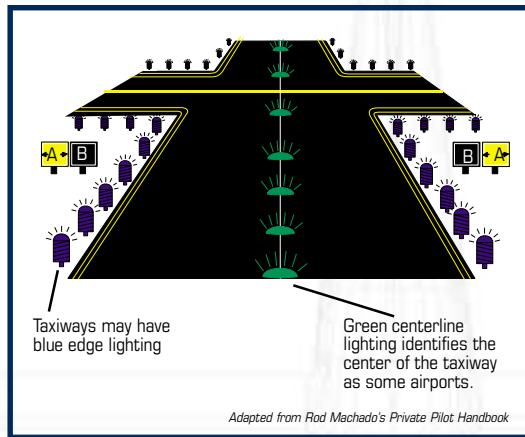


Figure 7-6 Taxiway Lighting.

One time, I caught an empathetic and sensitive student of mine weaving between the embedded green taxiway lights. I thought she was having a Nyquil® flashback until I found out that she was afraid of damaging either the lights or the tires. You won't hurt the lights or

the tires, but feel free (if you wish) to keep the nosewheel a few inches to the side of the embedded lighting.

As a pilot, you must be able to identify the point where the taxiway ends and the runway begins. This transition is identified by four yellow lines—two solid and two dashed—crossing perpendicular to the taxiway and running parallel to the runway (Figure 7-7). These markings are known as runway-hold markings.

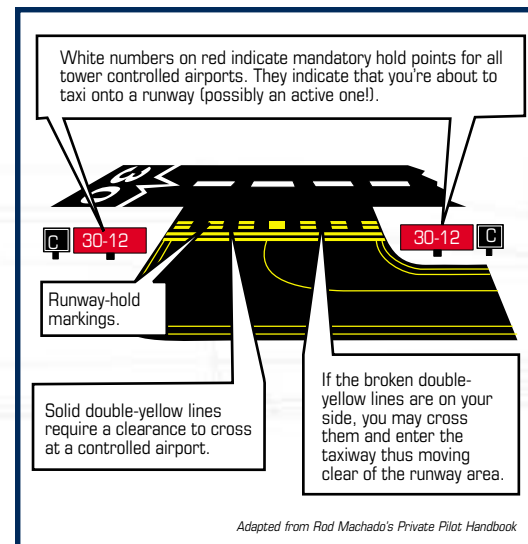


Figure 7-7 Taxiway Markings.

CLASS 7: TAXIING THE AIRCRAFT

If the two solid lines are on your side, then, at a tower-controlled airport, a clearance is required to enter the runway. If the double dashed lines are on your side, then you should cross those lines to clear the runway and enter the taxiway. (From now on, we'll assume that a controlled airport is one having an operating control tower.)

Assuming you have just landed and are taxiing off the runway, you should taxi across the double dashed lines and clear the runway. The FAA assumes that your airplane hasn't cleared the runway until the entire airplane (down to the last rivet) is on the other side of those double dashed yellow lines. The reason for this is to prevent the tails of long airplanes (like a stretched DC-8) from poking out onto the runway. This could make landing quite challenging for another pilot and possibly give him or her an extra EKG blip.

At airports without an operating control tower (meaning the airport has no control tower or the tower has shut down for the night), entering an active runway is done at the discretion of the pilot.

(From now on, an airport having no control tower or one at which the tower is not in operation will be referred to as an uncontrolled airport.) In this instance, you should hold short of the runway, behind the solid taxiway-hold lines. Taxi onto the runway only when it's clear of traffic and no airplanes are on a short final (getting ready to land). In other words, "Look carefully before taxiing onto the runway." The last thing you want is for someone to do a touch and go on you. And, making another pilot go around won't win you too many friends at the airport. It's also a good idea to broadcast your intentions on something known as the Common Traffic Advisory Frequency (CTAF) when no tower is in operation. This lets other pilots in the traffic pattern know what you're doing. More on this later.

Another way to identify where the runway begins is with a white-on-red sign located next to the dashed and solid double yellow lines (Figure 7-7). These informational billboards are called runway-holding signs, though they don't actually hold anything. They exist to inform you when

CLASS 7: TAXIING THE AIRCRAFT

you're about to enter an active runway. They also indicate the runway direction. In Figure 7-7, 30-12 indicates Runway 30 is to the left and Runway 12 is to the right (in other words, go to the left to find the beginning of Runway 30, and so on.). At controlled airports, these signs are your cue to hold your position unless a clearance has been given to enter or cross the runway. Figure 7-8 shows a single runway-holding sign indicating that the taxiway intersects the beginning of the takeoff runway.

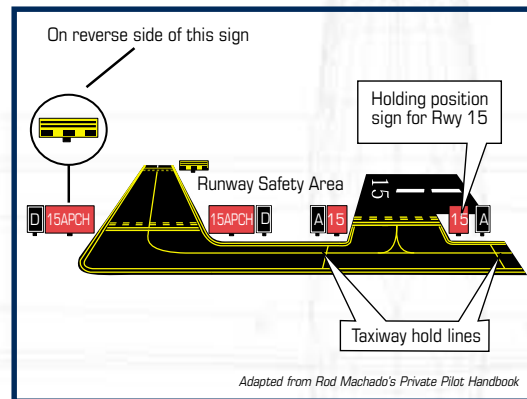


Figure 7-8 Taxiway Lighting.

At uncontrolled airports, the runway-hold signs indicate that you can proceed across or onto the runway when you've assured yourself no traffic conflict exists (an airplane preparing to take off or land is most definitely a conflict). At a tower-controlled airport, these signs are coupled with the double solid and dashed taxiway-hold lines, providing ample warning that you're crossing into the action area.

Some airports may have taxiways that interfere with the runway safety area, as shown in Figure 7-8. Taxiway Delta is located directly behind the beginning of Runway 15. Airplanes landing on Runway 15 could approach low enough to present a problem to both the approaching and taxiing airplanes. This is more likely to be a problem for big airplanes, but the rules take into account the worst-case scenario. Holding-position signs for this peripheral runway are shown by white-on-red lettering. The term 15APCH next to the solid double yellow lines indicates a mandatory hold point at tower-controlled airports (this means any

CLASS 7: TAXIING THE AIRCRAFT

aircraft on the following taxiway might affect aircraft on approach to Runway 15). On the opposite side of the runway, on Taxiway Delta, on the back side of the runway-hold sign, is a runway safety area sign (normally found only at tower-controlled airports). This consists of the same markings shown on the taxiway (double solid and dashed lines). These signs can be used as a guide in deciding when to report back to a controller that you are clear of the runway. Remember, at uncontrolled airports, pilots must decide for themselves whether to enter or cross a runway.

It's difficult, but not impossible, for pilots to accidentally taxi onto an active runway at a tower-controlled airport. One pilot at a busy airport once taxied right into the middle of an active runway and just sat there (probably waiting for one of those yellow trucks to bring him a sandwich). Completely confused about the tower's directions and unwilling to ask for clarification, he stopped his airplane while a jet

was on final approach. The tower controller said, "32 Bravo, do you know where you are?" The pilot replied, "Burbank Airport?" The controller said, "Yes, that's good, but do you see that big Boeing 707 out there on final approach headed directly for you?" The pilot replied, "Yes." "Do you want him to do a touch and go on you?" The pilot replied, "No." The controller said, "Then you'd better get off his runway." The pilot, not wanting to get bounced on by a Boeing 707, immediately exited the runway.

Additional Runway Markings

Just because there is concrete in the shape of a runway doesn't mean that it can be used for landing. Some runways have yellow chevrons painted on them (Figure 7-9, position A). This signals that the surface is unsuitable for taxiing, taking off, or landing. It's basically an airplane no man's land. Don't use any portion of this area. It might be off-limits because the surface won't support the

CLASS 7: TAXIING THE AIRCRAFT

weight of an airplane even for taxiing, let alone landing, or because the surface is otherwise unsuitable. Planes that venture onto chevrons can find themselves up to their axles in asphalt and trapped like a gigantic fly on a No-Pest™ strip.

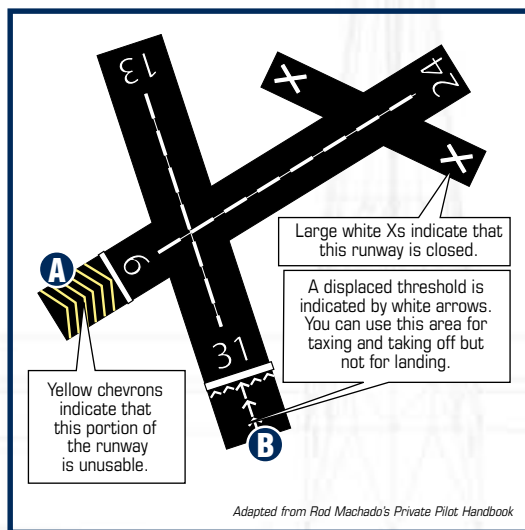


Figure 7-9 Runway Surface Markings.

White arrows pointing in one direction form what is called a displaced threshold (Figure 7-9, position B). This is a runway area that is not to be used for landing, but on which you can taxi, take off, or roll out after landing. Displaced thresholds often exist as part of a noise abatement effort. By forcing you to land farther down the runway, you maintain a higher altitude on the approach than you would if landing at the beginning of the runway. A displaced threshold can exist for other reasons, such as the presence of a surface that will support the weight of an airplane, but not the impact of an airplane landing. (There's a big difference. I know this since one of my instructors used to call out Richter scale values following my touchdowns.)

CLASS 7: TAXIING THE AIRCRAFT

I won't mention any names, but on occasion, professional airline pilots have been known to land at the wrong airport with a full load of passengers. Nothing like bringing your own audience to a faux pas. Several years ago, a pilot did this at an East Coast airport. He accidentally landed at a small training field with nothing but itty-bitty Cessnas and Pipers fluttering around the pattern. As he touched down and came to a stop, his wheels punched holes in the thin runway surface. He knew he was in trouble when it took full power just to taxi. A few of the locals came out and said, "Hey! Look what you did to our runway! You put divots in it. Geesh!" The only way they could get the airplane out was to completely strip it down to barebones metal, making it light enough to take off without further runway damage. The same could not be said for the pilot's career.

CLASS 8: STALLS

First, a Little Theory

In our class on slow flight, I showed how, in order to maintain sufficient lift for flight, the wing's angle of attack increased as the airspeed decreased. Perhaps you've wondered if there is a limit to how much the angle of attack could increase. After all, common sense suggests there are limits to all things. The ancient Egyptians had common sense limits, especially regarding the size of pyramids they could build (I think this is known as *Tut-an-kommon* sense). Wings have limits, too.

Air begins to burble over the top of the wing when the wing reached a large angle of attack (about 18 degrees for most airplanes). The angle at which the air begins burbling, followed by the wings stalling is known as the critical angle of attack.

Okay, here comes an idea that's like the biggest fish you ever caught—it's a real keeper. Since wings always stall when they exceed the critical angle of attack, you can recover from the stall by decreasing the angle of attack to less than the critical value. Everybody got that? Repeat it to yourselves 10 times, fast.

Stall, Angle of Attack, and How the Nose Knows

A pilot's job is to work the four forces, maintain lift, and avoid the burbling air condition that results in a stall.

Think of air molecules as little race cars moving over the wing (Figure 8-1). Each car and air molecule has one objective: Follow the curve over the wing's upper cambered surface. Of course, if the wing is at a low angle of attack, the curve is not sharp, and it's a pretty easy trip (Figure 8-1A).

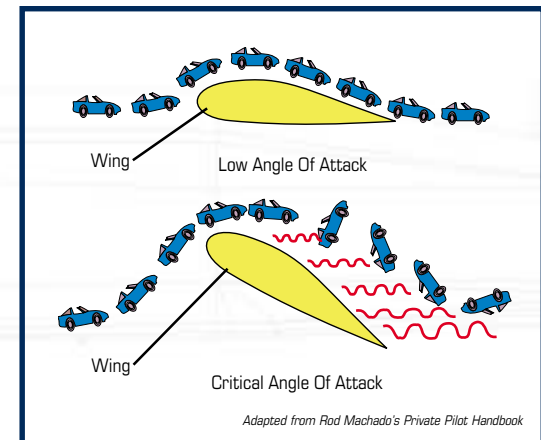


Figure 8-1 Angle of attack.

CLASS 8: STALLS

But look at the curve made by these cars and air molecules when the wing is attacking the wind at a large angle. As the angle of attack exceeds approximately 18 degrees (known as the critical angle of attack for reasons you will soon see), these speed-racer air molecules don't negotiate the turn (Figure 8-1B).

When this happens, they spin off, or burble, into the free air, no longer providing a uniform, high-velocity, laminar airflow over the wing (Figure 8-2). The wing stalls.

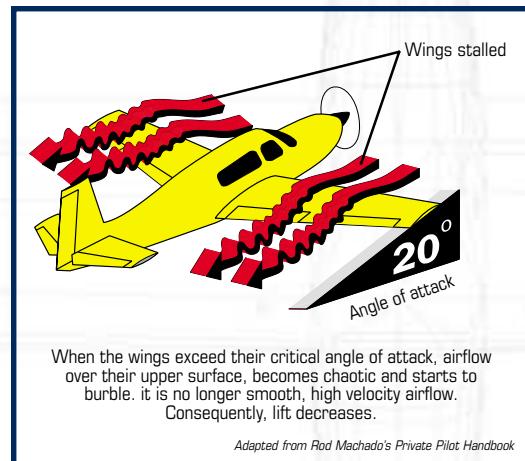


Figure 8-2 Stalled vs. Unstalled Wings.

Remember, according to Bernoulli, lower-velocity airflow over the wing produces less lift. There is still impact lift provided by air molecules striking the underside of the wing, but we've already learned this doesn't provide nearly enough lift to sustain the airplane. When there's less lift than weight, bad things happen to good airplanes. The wing goes on strike and stalls. Abandoned by Bernoulli, gravity summons the airplane to earth on its own terms.

All wings have a critical angle of attack (the angle varies slightly among airplanes). Beyond this angle, the wing and the wind don't work and play well together. All the whispered theory in your heart won't overcome the laws of physics and aerodynamics. The wing police are always watching. Exceed the critical angle of attack, and the air molecules won't give you a lift. Sounds serious—and it can be. Fortunately, there's a readily available solution, and it is not screaming, "Here, you take it!" to the instructor. At this point, I'd like you to put your finger in your ear. Why? Because I'm about to say something really important and I don't

CLASS 8: STALLS

want it to go in one ear and out the other. Here comes the important stuff again. You can unstall a wing by reducing the angle of attack. You do this by gently lowering the nose of the airplane using the elevator control (Figure 8-3 A&B).

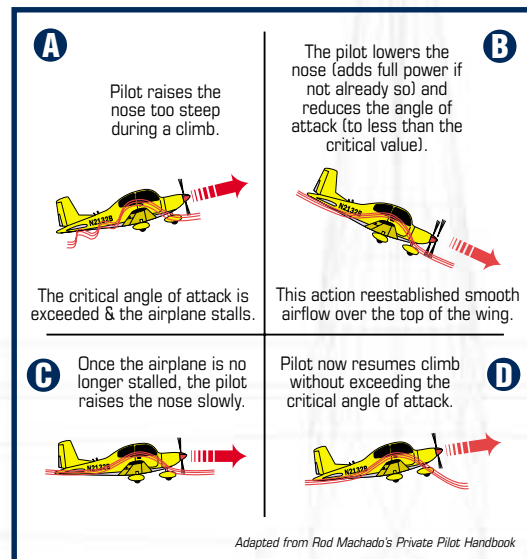


Figure 8-3 Stalling and exceeding the critical angle of attack.

Easy does it here, Tiger. Once the angle of attack is less than its critical angle, the air molecules flow smoothly over the top of the wing and production of lift resumes. It's as simple as that. Now the airplane can resume flying and doing what airplanes are supposed to do (Figure 8-3 C&D). Please don't ever forget this. Okay, you can take your finger out of your ear now.

Why am I making such a big deal out of this? Because in a moment of stress (having the wing stop flying creates stress for many pilots), you will be inclined to do exactly the opposite of what will help. Pilots have a natural inclination to pull or push on the elevator control to change the airplane's pitch attitude. During a stall, as the airplane pitches downward, your untrained instinct is to pull back on the elevator control. You may yank that critter back into your lap, and the result will not be good. The wing will remain stalled, and you, my friend, will have the look of a just-gelded bull.

CLASS 8: STALLS

If the wing stalls, you need to do one very important thing: Reduce the angle of attack to less than its critical value. Only then does the wing begin flying again. Adding full power also helps in the recovery process by accelerating the airplane. The increase in forward speed provided by power also helps reduce the angle of attack.

Don't just sit there with stalled wings. There's a reason why you are called the pilot in command. Do something. But do the right thing.

Stall at Any Attitude or Airspeed

You should realize that airplanes can be stalled at any attitude or at any airspeed. Put your finger back in your ear. It makes no difference whether the nose is pointed up or down or whether you are traveling at 60 or 160 knots. Whether an airplane exceeds its critical angle of attack is independent of attitude or airspeed. Figure 8-4A shows one instance of how this might happen.

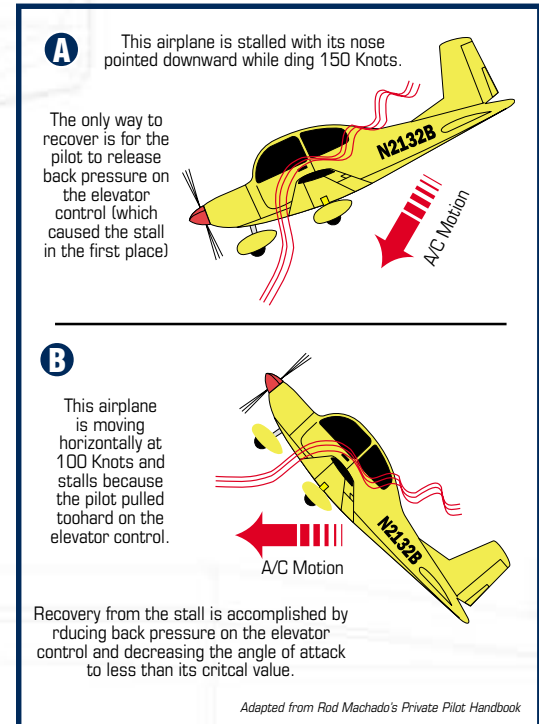


Figure 8-4 Stall recovery when exceeding the critical angle of attack.

CLASS 8: STALLS

Airplanes have inertia, meaning they want to keep on moving in the direction they are traveling. Airplane A is pointed nose-down, diving at 150 knots (don't try this at home!). The pilot pulled back too aggressively, forcing the wings to exceed their critical angle of attack, and the airplane stalled. Wow! Imagine that. It stalls nose-down at 150 knots! Figure 8-4B shows an instance of an airplane stalling at 100 knots in level flight after the pilot pulled too abruptly on the elevator control.

What must the pilot do to recover? The first step is to decrease the angle of attack by moving the elevator control forward or by releasing back pressure on the control wheel/stick (remember, pulling back on the elevator control was probably responsible for the large angle of attack that induced the stall in the first place.) This re-establishes the smooth, high-velocity flow of air over the wings. The airplane is once again flying.

The second step requires applying all available power (if necessary) to accelerate the airplane and help reduce the angle of attack.

Once the airplane is no longer stalled, it should be put back in the desired attitude while making sure you don't stall again. Stalling after you've just recovered from a previous stall is known as a secondary stall. Unlike secondary school, it is not considered a step up, especially by the participating flight instructor. (You'll know your instructor is unhappy when you hear her make subtle statements like, "Hmm, come to think of it, childbirth wasn't all that painful.")

Stalling an airplane intentionally, at a safe altitude, is actually fun, or at least educational. Stalls are relatively gentle maneuvers in most airplanes. Stalling an airplane close to the ground, however, is serious business because it is usually not an intentional act. During flight training, you'll have ample practice in stall recovery.

Managing a stalled airplane is one thing; managing your natural instincts, however, is another. For example, a typical stall trap you could (literally) fall into involves a high sink rate during landing. While on approach, you might apply back pressure on the elevator attempting to shallow the

CLASS 8: STALLS

descent. If you exceed the critical angle of attack, the airplane will stall. The runway now expands in your windshield like a low-orbit view of a supernova.

If you follow your untrained instincts and continue to pull backwards on the elevator, the stall deepens. Trained pilots know better. They are aware of the possibility of stalling and apply the appropriate combination of elevator back pressure and power during landing to change the airplane's glide path without exceeding the critical angle of attack (your instructor will show you the appropriate use of elevator and power during landing). How do pilots know the proper amount of rearward movement to apply to the elevator? How do they know they won't stall the airplane?

If there was an angle of attack indicator in your airplane, stall recognition would be easy. You'd simply keep the angle of attack less than what's critical for that wing. Angle-of-attack indicators, although valuable, are rare in small airplanes. In Flight Simulator, the main clue you have to the onset of a stall is the stall horn, which will

activate when you're a few knots above stall speed. You'll also have the luxury of seeing the word STALL appear on your screen. You won't have this in an actual airplane, of course. You may, however, have a red stall warning light activate, which is almost the same thing.

Now that you have a good foundation in stall aerodynamics, let's examine the details of stall recovery.

Stop Flying; Start Stalling

Pulling way back on the joystick caused the wings to exceed their critical angle of attack and stall. During the stall, airflow burbles instead of flowing smoothly over the top of the wing. This results in insufficient lift for flight, causing the airplane to pitch forward (it pitches forward if the baggage, passengers, and fuel are loaded properly in the airplane). This automatic nose-down pitch is somewhat like doing the Heimlich maneuver on yourself; the airplane reduces its own angle of attack to less than the critical value and regains its ability to fly.

CLASS 8: STALLS

If airplanes are built to recover from stalls themselves, why do you need to learn any of this? The problem is that pilots often do things that prevent stall recovery. You need to know what these things are. Also, an accidental stall close to the ground requires that you know how to quickly recover in order to minimize your altitude loss. Let's try another stall, but this time, let's see what happens if you prevent the airplane from pitching forward on its own.

Doing the Wrong Thing in a Stall

What happens if we stall and prevent the airplane from recovering from the stall?

The answer is that the airplane will remain stalled with the joystick held full aft. It will not climb, no matter how hard you pull on that joystick. Think about this carefully. You could remain stalled all the way to the ground while the joystick is pulled full aft (that's all the way back), which doesn't bring you much joy, right? Holding the joystick full aft keeps the wing's angle of attack at or beyond its critical value. Unfortunately, this is what some pilots do after stalling an airplane.

Doing the Right Thing in a Stall

That's why we learned that you must release any back pressure on that joystick and move it forward until the wings are at less than their critical angle of attack. The proper attitude for recovery is subject to many variables, so in the Interactive Lessons, we'll use a 5- to 10-degree nose-down pitch for simulator stall recoveries. You don't want an excessively steep nose-down attitude since it results in excessive altitude loss and airspeed increase.

How do you know if you've decreased the angle of attack sufficiently? In a simulator, you should experience these things: the stall horn stops blaring, the word STALL disappears from the screen, the airplane begins to fly again, the airspeed begins to increase, and the flight controls become more responsive. If your instructor were onboard, his or her voice would also reduce in pitch, and whales would no longer be inclined to beach themselves.

With a few exceptions, this is the way pilots have always recognized stalls and recovered from them. You'll also want to add full power immediately after reducing

CLASS 8: STALLS

the angle of attack. This helps accelerate the stall recovery process. Be careful not to let the nose pitch up as you add power. This might, once again, increase the angle of attack sufficiently to induce another stall. When the airplane is no longer stalled (that is, the stall horn stops blaring), raise the nose to climb attitude, and establish climb airspeed.

Departure Stalls

What happens if you stall with full power already applied? Let's say that you've just lifted off from an airport and are climbing with full power (as you normally do in this airplane). Suddenly, you find a big bumblebee in the cockpit. You're distracted and forget to fly the airplane as you swat the critter with both hands. Of course, all your flailing in the air makes the cockpit look like the set of a kung fu movie as the airplane stalls. What do you do?

Well, Grasshopper, all the kung fu in the world won't help you now unless you do one thing: Reduce the wing's angle of attack to less than its critical value. Once the airplane is no longer stalled, you can recover back to climbing attitude. Don't worry about touching the throttle, since full power is already applied.

There you have it: your first introduction to the aerial theme park known as Stall World. The only problem, however, is that you didn't visit one corner of the park called Reality Land. Here's what you missed.

It's easy to remember that airplanes stall because they exceed their critical angle of attack. But don't forget that this can happen in any attitude, at any airspeed, and at any power setting. Time now for more truth.

In reality, if the airplane was pointed straight down and you pulled back hard enough on the controls, the airplane would stall. Of course, we wouldn't do this in the actual airplane (even if it was a rental). Remember, this is a simulator. We can do things you'd never dream of doing in a real airplane. It's like visiting Fantasy Land in that we're not exposed to great risk in the demonstration. So we can take advantage of our technology and see what others only talk about and never actually do. Why don't you practice stalls now in Private Pilot Lesson One? Have fun!

CLASS 9: STEEP TURNS

I like steep turns! They're fun, challenging, and, in many cases, they are a good test of a pilot's ability to recognize the limits of airplane performance. And, if you play Microsoft® Combat Flight Simulator, they're useful to get away from a bandit who is trying to shoot your tail off!

Steep turns (those typically done between 45 and 55 degrees of bank) are used to develop flight proficiency. Practice them often, and you'll find yourself becoming smoother on the flight controls. Steep turns also help you learn to handle the natural division of attention that accompanies such a high-performance maneuver.

There's another benefit of which you may not be aware. Steep turns demonstrate that airplanes have limits and exceeding those limits has a cost. Making too steep a turn can result in a stall. This isn't necessarily dangerous if you're several thousand feet above the ground. However, don't try making a steep turn to align yourself with the runway when you're at a low altitude with insufficient airspeed. This is a surefire way to get into a new line of work, like geology. You'll really get into it—about six feet deep into it.

Steep Turn Aerodynamics

First, a little review. In an earlier class, you learned that banking the wings allows lift to pull the airplane sideways. The airplane turns because some of its lifting force acts in the horizontal direction.

Of course, once an object is set in motion, it wants to remain in motion. A fellow named Newton said that (that's Isaac, not Wayne). When an airplane turns, its entire mass still wants to maintain its original direction. That's why you feel yourself forced down in your seat on a roller coaster when the track changes direction. The roller coaster is changing directions, but your body wants to continue moving straight ahead. Coupled with the downward pull of the earth, you feel like you'll go right through the roller coaster's seat.

While airplanes don't fly on tracks, you'll feel a similar force pulling you down in your seat when making a steep coordinated turn. The steeper the turn, the greater the seat-pulling force. This force is sometimes called the G-force (or load factor). The "g" in G-force is derived from the word "gravity" and has nothing to do

CLASS 9: STEEP TURNS

with the sound passengers make when they feel themselves forced down in their seats during steep turns: “Gee!”

G-force is a predictable force for all airplanes. Figure 9-1 shows a graph representing the increase in G-force for a given bank. The example shows that in a 60-degree bank, you and the airplane will feel a G-force of 2 (2 Gs). In other words, you and the airplane feel like you weigh twice as much as you normally do. Imagine that. You experience an apparent increase in weight, all without letting even one bag of greasy fries slip past those disciplined lips of yours. Of course, you can lose that weight by rolling out of the turn back into straight-and-level flight, where you’ll feel a G-force of 1—just like you feel right now (which is determined by how many fries you’ve eaten up till this point in your life).

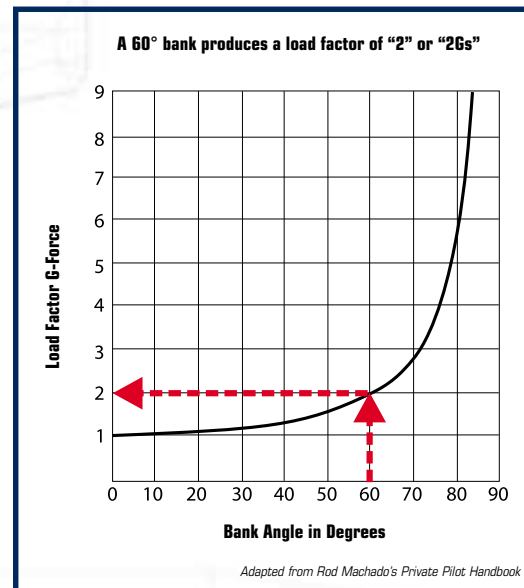


Figure 9-1 Load factor chart.

Here's the catch: If you and the airplane feel heavier because of an increase in G-force, then you, the pilot, must compensate for the artificial weight increase. You must increase the airplane's lift if it is to keep flying. Without compensating for

CLASS 9: STEEP TURNS

this, the airplane won't be able to maintain altitude in a steep turn. In fact, it can even stall. And you don't want to become known as a pilot who stalls whenever he or she makes a steep turn. Imagine the kind of nickname you'd get for that: Imelda Impact, Steve Splatdown, or Chris Crater.

Increasing lift in a steep turn means you must increase the angle of attack by applying back pressure on the joystick. Lift must equal weight—real weight or apparent weight—if the airplane is to remain flying. That's why steep banks require large angles of attack to produce the lift necessary for flight. You see what's coming, right?

If you make too steep a turn, the airplane may reach its critical angle of attack before producing sufficient lift for flight, and the airplane will stall. Now you're forced to recover from the stall before you can continue flying.

You've just learned that an airplane's stall speed increases in a steep turn. While you may stall at 50 knots in straight-and-level flight, you may need 70 knots to keep from stalling when turning steeply. Figure 9-2 is another graph, which allows you to predict this increase in stall speed based on an increase in G-force.

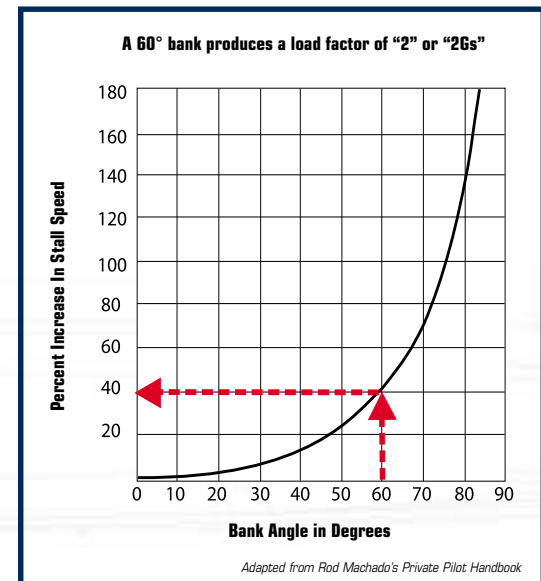


Figure 9-2 Stall speed and bank angle chart.

CLASS 9: STEEP TURNS

For example, in a 60-degree bank, the airplane and its contents experience 2 Gs (that's a G-force of 2). Figure 9-2 shows that 2 Gs give you a 40 percent increase in stall speed. Therefore, an airplane stalling at 50 knots in level flight will stall at 70 knots in a 60-degree bank (40 percent of 50 added to 50).

Here's what this means to you. If you're planning on doing a steep turn at 60 degrees of bank, you'd better have an airspeed of at least 70 knots if you want to avoid a stall. Isn't that amazing? You made a prediction and didn't need to peek at a magic crystal ball, throw bones, or read tea leaves (you can save these things for weather predictions).

That's why you'll need to add additional power when doing steep turns. In most cases, this provides the necessary increase in speed that helps prevent a stall. Of course, if your airplane doesn't have a big engine, then it may not be able to produce the thrust necessary to keep the speed high enough to prevent a stall during a steep turn. Well, I remember

going to a doctor and saying, "Doctor, it hurts when I do this!" Her advice, of course, was "Don't do that."

If you don't have sufficient power, then you can't go around making really steep turns. And the author's decision is final on that.

Don't worry about technique right now. You want to examine the aerodynamics first, and then we'll talk about the art of making turns.

What This Means to You

It appears that you need a 6-degree nose-up attitude to hold your altitude in this turn. Since your angle of attack increased, more of the wing's underside is exposed to the airstream. This creates more lift—but also more drag. Thus, the airplane slows down a bit, as shown on the airspeed indicator.

So, here's a problem for you:

- A steep turn with a constant altitude is accompanied by a decrease in airspeed.

CLASS 9: STEEP TURNS

- Coupled with an increase in stall speed, you may find yourself caught between the proverbial rock and a hard place if you're not careful.
- As the stall speed increases and the airspeed decreases, the two may eventually meet.

What happens then? Yes, the airplane stalls. How might you prevent this in a steep turn? Try adding power to prevent airspeed loss. Once again, don't worry about making beautiful steep turns yet; ugly ducklings are fine for right now. Hack your way through it, and I'll teach you the proper steps to the dance in a bit.

2 G or Not To G

Suppose you roll into a 45-degree bank and add full power. What will happen? You'll notice that the increase in power allows the airplane to maintain its airspeed. There you have it. A nice steep turn without a decrease in airspeed is possible as long as you have sufficient

power. But suppose the turn is really steep? Let's say it's at 60 degrees of bank. At this bank angle, your stall speed increases from 50 knots to 70 knots. The question is, "Do you have enough power to keep the airspeed above 70 knots in a 60-degree bank turn?" The only way to find out is to try and experiment with this at a safe altitude. When you do this experiment, you'll find that the airspeed will decrease, even with full power. Why? Because small airplanes just don't have the extra power to overcome the enormous increase in drag associated with the required increase in angle of attack.

The Tough Part

Here's where pilots often get themselves into trouble. When maneuvering for landing with power at idle, they make steep turns to align themselves with the runway. Given their slow speed and steep

CLASS 9: STEEP TURNS

bank, the airspeed and stall speed converge. In other words, while in a steep turn, the stall speed increases because of increasing G-force and the airspeed decreases because of increasing drag. When the airspeed and stall speed meet, the airplane stalls. If this happens close to the ground, it's a real bad deal. You'll often hear this type of stall called an accelerated stall. It's accelerated because of the high G-force caused by a steep turn.

Okay, enough science, Mister Spock. Time for artistry. Let's talk about how to make classy steep turns.

A Touch of Class Before You're Out of Gas

One secret to making a good steep turn is to have a predetermined idea of the attitude necessary to hold altitude in that turn. While there are many variables affecting this, you can still approximate it. Normally, you'd also use outside visual references while doing steep turns in an airplane. This allows you to keep a lookout for other airplanes, as well as identify the

airplane's attitude. Using outside visual references for steep turns, however, is a little tough to do in a simulator, so you'll focus on the attitude indicator instead.

Take a look at Figure 9-3. This is the approximate attitude necessary for a turn at 45 degrees of bank. As you roll into the turn, you'll need to progressively increase the pitch until you reach a 6-degree nose-up attitude. Then, you should use the altimeter to determine what type of small pitch correction is necessary to hold altitude. You can also use the VSI as an additional source of information, if you like. The secret is to make small corrections and always keep an eye on your attitude.

CLASS 9: STEEP TURNS



Figure 9-3

Overcorrection is sure to send you wandering all over the sky as you try returning to your assigned altitude. A steep turn is considered acceptable by private pilot standards when the following things are all true:

- Your altitude doesn't vary more than 100 feet.
- The heading on rollout is within 10 degrees of the direction you started with.

- The bank varies no more than 5 degrees.
- The airspeed remains within 10 knots of the entry speed.

There's one other thing you should be aware of when doing steep turns. Pulling back on the joystick tends to increase the bank a little. That's why you must be careful not to let the bank increase during a steep turn. This is a rather common occurrence when applying back pressure on the joystick. Additionally, at steep bank angles, airplanes have a natural tendency to steepen their bank without the pilot doing anything to cause this. Once again, be prepared to compensate for this with aileron pressure if necessary. Therefore, in a steep turn, especially when applying back pressure to maintain altitude, you might need to apply a little opposite aileron with the joystick to prevent overbanking.

Perhaps you're wondering why I haven't mentioned anything about trimming during the steep turn. The reason is that

CLASS 9: STEEP TURNS

we only use trim to hold the controls in one place for a relatively long period of time. Since steep turns are transitory, trim isn't normally used. Besides, steep turns help you to recognize the onset of an accelerated stall. In the actual airplane, you can feel yourself being forced down in the seat by increasing G-force. You can't feel this in a simulator. Therefore, you must rely on the back pressure you're applying to the joystick to warn you of an approaching stall at higher airspeeds. This is another good reason not to trim in steep turns.

You're now qualified to try steep turns at larger banks. When you practice them in the Interactive Lesson, go all the way to 55 degrees, which is the bank required

for commercial license certification. Roll into and out of the turns while holding altitude within 100 feet, airspeed within 10 knots, and rollout headings within 10 degrees of the entry direction. Have as much fun as you can! It's time for you to practice steep turns in the Private Pilot Lessons.

In the next ground school session, I'll show you how to keep your traffic pattern at an airport from becoming a tragic pattern.

CLASS 10: THE TRAFFIC PATTERN

Airplanes are like homing pigeons: they all have a particular place to go. In the case of airplanes, it's the airport. For homing pigeons, they head...home. With all those airplanes heading for airports (in some cases, the same airport), it's amazing that they don't bump into one another more often. In the spirit of the homing pigeon, I guess you could say that pilots pull off quite a "coo" in how they manage to do this safely. The fact is, pilots are highly organized when they operate at airports. They don't fly around in a chaotic manner like moths around search lights. They fly a rectangular pattern relative to the runway, and they do it at a specific altitude. This pattern is formally called a traffic pattern, and it allows pilots to know where to look for and expect other aviators that are operating at the airport. It's also the pattern you'll fly when you want to practice your takeoffs and landings. Let's have a closer look at how to fly the traffic pattern.

Flying around an airport is done in precise, careful ways so we don't run into each other and so we set ourselves up for good landings, aligned with the runway. This approach and alignment with the runway is called a traffic pattern—a rectangular pattern as shown in Figure 10-1. It has five major legs, or segments:

- The departure leg
- The crosswind leg
- The downwind leg
- The base leg
- The final approach

Let's review each segment and discuss its purpose. And since we can imagine this any place we want, why not imagine ourselves at the beautiful Honolulu airport?

CLASS 10: THE TRAFFIC PATTERN

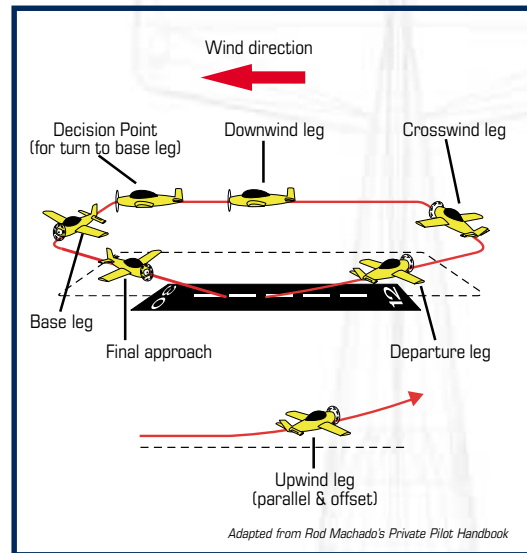


Figure 10-1 The traffic pattern.

The Departure Leg

The departure leg is the takeoff, which we've already covered. I guess you could say that we're off to a good start since we already have a leg to stand on.

Crosswind Leg

Since you'll remain in the traffic pattern for training, you'll make a 90-degree left turn (most traffic patterns use left turns) to the crosswind leg. This portion of the pattern is called the crosswind leg because the flight path is perpendicular to the runway and generally crosswise to the wind direction. Make this turn when the airplane is beyond the departure end of the runway and within 300 feet of traffic pattern altitude (TPA). (TPA is the maximum altitude at which you'll fly the pattern.) For this ground school class, let's set the pattern at 1,000 feet MSL, which puts you approximately 1,000 feet above the ground (and the water, too, so watch out for flying fish.)

Throughout the departure and crosswind legs (and sometimes part of the downwind leg, too), the airplane may continue to climb until reaching traffic pattern altitude. This depends on how close you fly the pattern, as well as airplane performance, runway length, and the number of hula dancers you have in the airplane with you. If you reach TPA while you're

CLASS 10: THE TRAFFIC PATTERN

still on the crosswind leg, then level the airplane at 1,000 feet, accelerate to 90-95 knots, reduce the RPM to 2000, and trim. It's also best to limit your turns to no more than 30 degrees of bank while operating in the pattern. This is no time to practice your combat turn techniques; besides, the war has been over for many years.

The Downwind Leg

As the airplane continues on the crosswind leg, another 90-degree turn is made. This places the airplane parallel to the runway, going opposite the direction in which it will land. This is called the downwind leg (point C) because you're now going with the wind instead of into it.

Fly the downwind leg at between half a mile and one mile out from the landing runway. There are several reasons for this. First, this position allows you to remain comfortably close to the runway. That way, in the event of an engine problem, you can glide to a safe landing on the runway instead of ending up in someone's lobster trap. Second, it keeps you close enough to the runway so you can see it easily. It makes no sense to fly

so far from the side of the runway that it looks like the end of a tiny matchbox. Being closer means you can more easily estimate wind drift and make the necessary wind corrections.

The problem is, how do you know when to begin the downwind turn? There are several ways to do this. In an actual airplane, you can look out the left window and estimate the distance. You can also do the same in Flight Simulator by selecting the side window view long enough to view the runway, and then switching back to the forward view. (Or, you could use the handy Virtual Cockpit feature we discussed earlier. Neat, huh?) You can also guess the distance by doing a little math. At 60 knots groundspeed, the airplane covers one nautical mile in one minute. Therefore, you'd want to begin the downwind turn anywhere between 30 and 60 seconds after turning crosswind. Since your airplane is climbing at 75 knots (75 knots groundspeed assumed), you'll want to begin the turn sooner, perhaps between 24 and 48 seconds after turning crosswind. Perhaps the easiest way is to use Flight Simulator's Top-Down view to estimate the turning point.

CLASS 10: THE TRAFFIC PATTERN

Finally, how do you know what direction to fly the downwind leg? That's an easy answer. Fly a heading exactly opposite of that used for takeoff. Without doing any math, just look at the number shown at the bottom of the heading indicator when you're aligned with the runway. That's the heading you'll fly on the downwind leg.

Preparing for the Base Leg Turn

You'll continue downwind until passing a point abeam the threshold of the landing runway. At this point, you want to begin preparation for landing by applying 10 degrees of flaps. (Make sure you're below 95 knots when applying flaps. The end of the white arc on the airspeed indicator is the airplane's maximum flap-extension speed.) Here's the sequence you might use in this instance:

1. When you are abeam of the end of the runway, apply 10 degrees of flaps.
2. Adjust the pitch using the joystick to hold altitude.

3. Trim the airplane. (Remember, don't use trim to change the pitch. That's what the joystick's for. Use trim to take the pressure off the joystick once the desired attitude is established.)

It's important to hold your altitude on the downwind leg. After all, airplanes are entering the pattern on the downwind leg, and a premature descent from TPA could result in a landing on someone's airplane (perhaps this is how biplanes were invented).

Base Leg

Now it's time for another 90-degree turn to the left. We call this base leg, and from here you have only one more 90-degree turn before you're on final approach. But where should you start your turn to base leg?

Assuming airplane traffic isn't a factor, it's convenient and practical to start your turn onto base leg when the landing threshold appears about 45 degrees between the wing (left wing in this instance) and the tail of your airplane. In

CLASS 10: THE TRAFFIC PATTERN

other words, as you look out the left window, the runway's threshold appears to be at a 45-degree angle to the left of the wing (or midway between the wing and the tail) as shown in Figure 10-2. This provides for a symmetrical, rectangular traffic pattern, instead of one having the shape of an enormous amoeba. Additionally, it provides you with enough distance from the runway to make a comfortable approach.

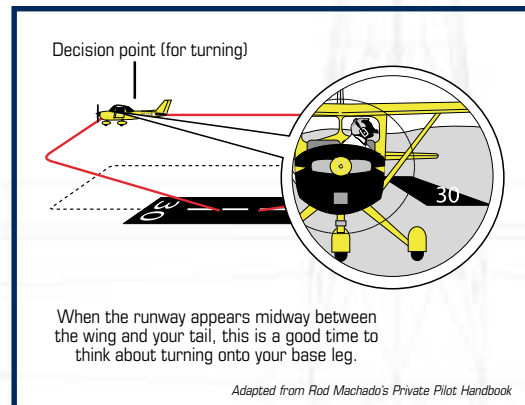


Figure 10-2 The traffic pattern

Yes, if you need to, you can look out the left window to estimate when you're in the position to turn onto the base leg.

However, you might be better off using Flight Simulator's Top-Down view to estimate the turning point, as shown in Figure 10-3.



Figure 10-3

Base leg is a point of transition for landing. It's the place where important adjustments are made in the airplane's speed and landing configuration. This is why, even when you're not following other traffic (airplanes) on the downwind leg, you should avoid turning base too early. Things happen mighty fast as you approach the runway. You want to give yourself enough time to adjust your

CLASS 10: THE TRAFFIC PATTERN

airspeed, flaps, and glidepath. That's why I recommend you give yourself a final approach length of at least a mile. Sometimes, it's preferable to modify the pattern and fly the downwind long enough so you'll have a final approach length of two miles. Assuming that you aren't following other airplanes in the pattern (or being followed), a longer final approach gives you much more time to configure the airplane for landing. When I'm introducing a pilot to a new and perhaps faster airplane, I typically tend to prefer to fly a longer final approach.

The descent for landing is normally started on base leg and continues throughout the final approach. Here's the sequence:

1. When the airplane is in the desired position to begin the base leg turn (as you look straight down in Top-Down view), make a 90-degree turn to the left. To easily identify the proper heading to fly, look at the heading that is 90 degrees to the left of the downwind heading. That's the heading to fly on base leg.

2. Roll out on this heading.
3. Reduce power to flight idle.
4. Establish a glide at 70 knots (when possible, I like to use a speed 40 percent above the no-flap stall speed on base leg).
5. Make sure you trim for 70 knots.

Now you're ready to intercept the final approach leg.

Final Approach

The final approach (sometimes just called final) is a critical part of the landing sequence. Generally, a square turn from base leg onto final approach is best. This provides you with enough time to observe and modify your airplane's descent path and alignment with the runway. During the final approach, the airplane is configured for landing and the speed is adjusted for the final approach speed (usually 30 percent above the airplane's present stall speed). Once the airplane is established and stabilized on a final

CLASS 10: THE TRAFFIC PATTERN

approach descent, you're now in a position to estimate whether or not your glidepath is too high, too low, or just perfect for landing on the desired portion of the runway.

When turning from base leg onto final approach, you have an opportunity to correct your glidepath for any obvious indications of being too high or too low.

Let's assume that you are making a power-off approach from the base leg. After turning base, you reduced the power and commenced a descent. Let's also assume that your objective is to land on a specific spot on the runway. If you're too low, you can cut short the turn from the base leg to final approach, as shown in Figure 10-4.

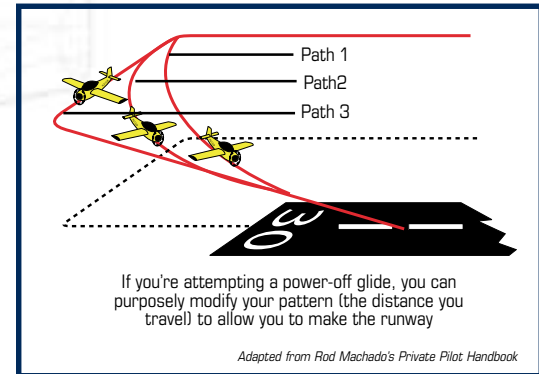


Figure 10-4 Pattern adjustments

Flying Path 1 allows you to fly less distance during the descent, thus increasing your chances of landing on the desired spot. Path 2 is longer; and Path 3 is a nice, square turn onto final.

If you're too high, you can deliberately overshoot the turn onto final approach, giving you more distance to cover during your descent, as shown in Figure 10-5. This is pictured in option B in the illustration.

CLASS 10: THE TRAFFIC PATTERN

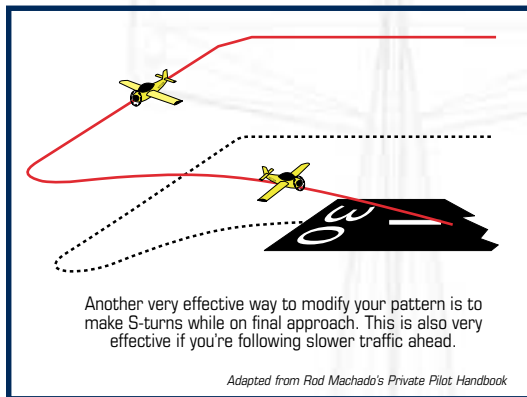


Figure 10-5 Pattern adjustments

Another option is to S-turn on final (Figure 10-6). S-turns are a series of alternating turns left and right of the direct glidepath. (They may make it look like you've had one too many Mai Tais!) Since the shortest distance between any two points is a straight line, anything you do to fly other than a straight line lengthens the trip. Assuming a constant rate of descent, taking the long way home will allow you to lose more altitude.

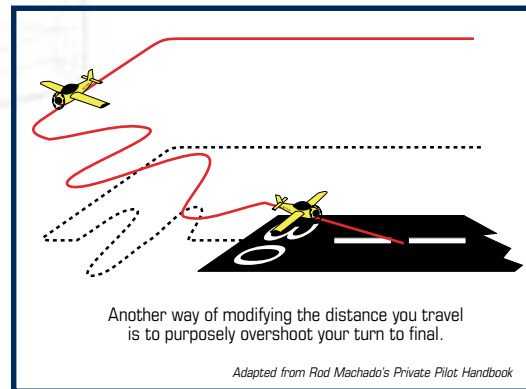


Figure 10-6. Pattern adjustments

Once you're lined up on final approach, establish a speed of 65 knots (if you decide to use 20 or 30 degrees of flaps, I recommend an approach speed of 60 knots). Don't forget to trim.

Now you're on your own and should be able to handle the landing from here! Practice the traffic pattern in the Private Pilot Lesson.

Okay, I think you're ready to try your hand at crosswind landings. If you thought that landings were fun before, wait till you try landing an airplane when the wind isn't blowing straight down the runway.

CLASS 11: CROSSWIND LANDINGS

What do a weathervane and a runway have in common? The answer is, nothing. While the weathervane points into the wind, the runway stays bolted to the earth, unmovable, stubborn, and that's all there is to it. The problem is that pilots like landing into the wind, which allows them to touch down at a slower speed, making the airplane easier to control. Pilots also like to land on runways, too. Therefore, when the wind blows crosswise to the runway, you have little choice but to land in this condition (unless you go searching for runways that have more favorable winds. This, however, isn't too practical). We call this a crosswind landing, and you're about to learn a few nifty tips and techniques on how it's done.

First, I'm going to assume that your simulator has rudder pedals or your joystick has twisting rudder functions. You need these to make crosswind landings. If not, I'll assume that you'll use the rudder functions of your computer's keyboard to manipulate the rudder. Using your fingers isn't quite the same as using your feet, but it will do the job nevertheless. For practical purposes, however, I'll just speak in terms of rudder pedals for this class.

Crosswind Conundrums

Learning to land in a crosswind involves only a few additional techniques beyond what you've already learned. All the essentials for landing should be comfortably etched in your brain by now. What we'll do is add a few more etchings to make you a complete pilot. We'll start with learning how to correct for crosswind drift.

There are two basic methods for correcting for drift during a crosswind approach and landing. The first is the crab method; the next is the wing-low (or sideslip) method. Let's examine how we crab an airplane to correct for wind drift; then we'll look at the wing-low method for accomplishing the same thing.

Crabbing

I suspect the term crabbing got its name from the observation of crabs as they walk. Crabs seem to point in one direction while walking in another. One might initially suspect that the toxic waste of highly polluted beaches might be responsible for this behavior. I don't know about you, but a little DDT always makes me walk funny. Fortunately, crabs walk funny

CLASS 11: CROSSWIND LANDINGS

for different reasons. I suspect it's just difficult for them to manage all those legs at one time. An airplane, however, can be said to crab when it points in one direction while heading in another. That's why the path your airplane traces over the ground is called its ground track.

If you sit there, fat, dumb, and happy with your compass showing a 165-degree heading, you will track a 165-degree heading over the ground from any given point only when there is no wind (or the wind blows directly on your nose or tail). A little wind, however, changes everything. Think of the wind as being a giant hand. Because the airplane doesn't have its feet on the ground, it gets pushed around by the wind. Depending on how much wind there is and what angle the hand is pushing from, the effect can be anywhere from slight to considerable.

The only way to create a straight ground track is to compensate for whatever wind there is by pointing the airplane's nose (slightly or more so, depending on conditions) into the wind (Figure 11-1). If you head the plane to the right a bit and the wind pushes to the left a bit, everything balances and you make your intended straight line over the ground.

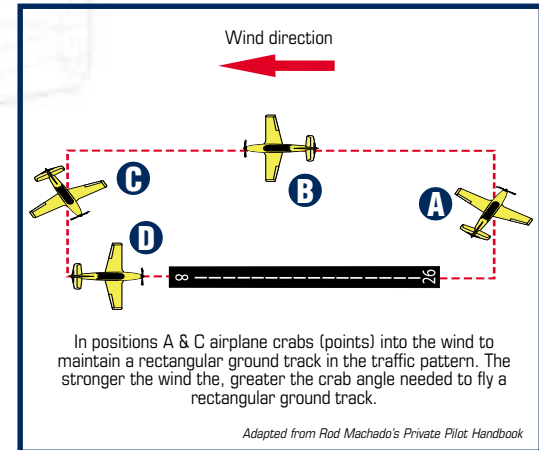


Figure 11-1 Correcting for wind drift within the traffic pattern

How do you know the precise amount to crab? Make a slight coordinated turn (say 5 or 10 degrees at first) into the wind, level the wings, and watch the results. Keep in mind that I said *coordinated* turn. We don't crab by applying only rudder. We use rudder and aileron in coordination to turn into the wind. Don't forget this. It's very important.

If the airplane is crabbed properly, it will make a rectangular ground track about the runway, as shown by the dashed line in Figure 11-1. The airplane's ground

CLASS 11: CROSSWIND LANDINGS

track is now perpendicular to the runway as flown by Airplane A. Similarly, Airplane C is crabbed to the left—into the wind—to maintain the desired ground track while on base leg. Of course, if the wind is not directly aligned with the runway, you'll have to crab on all five segments of the traffic pattern to maintain a rectangular ground track (Figure 11-2).

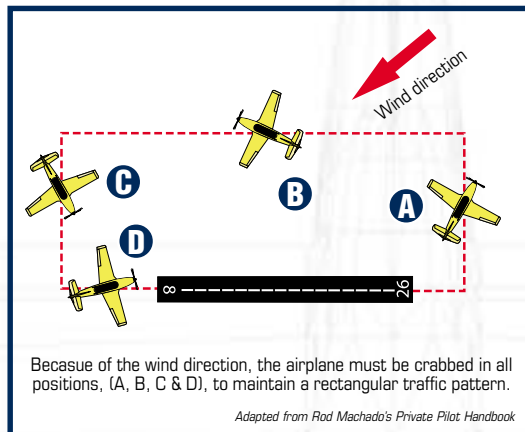


Figure 11-2 Crosswind correction within the traffic pattern.

If you let yourself get pushed around by the wind, you won't be where you're supposed to be. This is a particular

problem in the traffic pattern. Other pilots and the tower expect you to fly a traffic pattern that tracks straight on each leg, and crabbing to take account of the wind is the only way to do it.

Where crabbing becomes especially important is when you're lined up with the runway on final approach. That's why you want to turn into the wind and establish the proper crab angle as soon as possible so that your ground track is aligned with the extended runway centerline. It may take a few turns to find the proper crab angle. That's fine. Just do it.

Once the crab angle is established, you fly that angle all the way to the runway. In fact, you'll flare the airplane while still crabbing. It's only when the airplane is just about ready to touch down as it flares that you do something known as kicking out the crab.

Kicking Out the Crab

No, this has nothing to do with booting a grumpy instructor out of the airplane. It has everything to do with using sufficient rudder to align the airplane's longitudinal axis with the runway centerline before it

CLASS 11: CROSSWIND LANDINGS

touches down, as shown in Figure 11-3A. Yep, you just add sufficient rudder to straighten out the airplane before touching down. That's it. Okay, there is just one more thing.

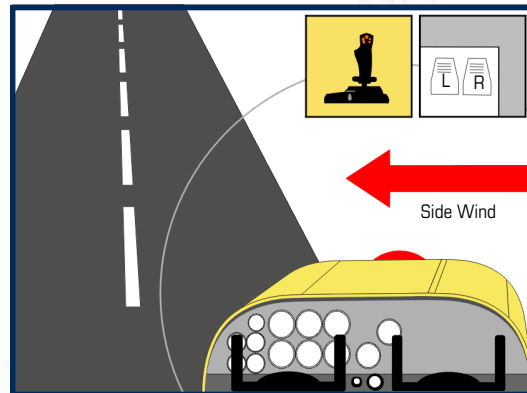


Figure 11-3A

If we assume that you are crabbing to the right, then you'll add left rudder to straighten out the airplane before touchdown. As you apply left rudder, the airplane will want to bank to the left. So you must add a tad of right aileron to keep the wings level as you kick out the crab, as shown in Figure 11-3B.

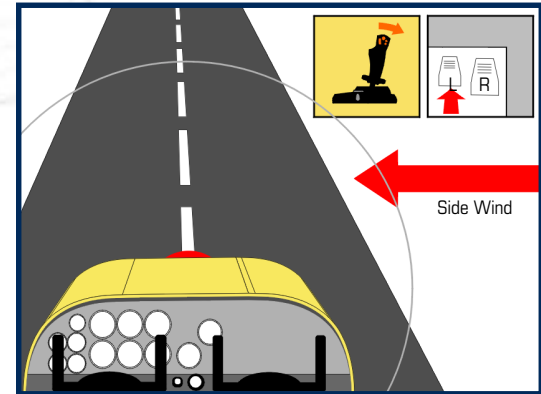


Figure 11-3B

The crabbing method isn't my preferred method for handling crosswind landings. It requires good timing to do it properly. To complicate things, as the airplane slows down during the flare, you often need to increase the crab angle to continue tracking down the runway centerline. The reason for this is that the airplane slows down during the flare, and a slower airplane requires a larger crab angle to compensate for wind drift. Therefore, as you flare, you often need to increase the crab angle and, just before the wheels touch down, you've got to

CLASS 11: CROSSWIND LANDINGS

straighten the airplane out again. Whew! That's a lot of work. Here's another way that's a lot easier on everyone: you, the airplane, and your passengers.

One Wing Low

This sounds like a maneuver invented by a Chinese flight instructor, doesn't it? To use the wing-low method of crosswind correction, all you need to do is bank the airplane in the direction of the crosswind. Use the ailerons to do this. If the wind is from the right, then add a little right aileron. This causes the airplane to slip sideways into the wind, as shown in Figure 11-4. This is also why the same method is known as the sideslip method of crosswind landing. If you bank sufficiently, then the sideways slippage of the airplane will cancel out the sideways push of the wind. The result is that the airplane tracks down the runway centerline. There is one additional thing you must do, however, to make this maneuver work.

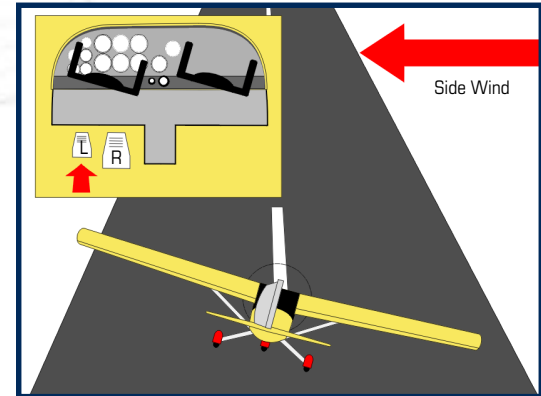


Figure 11-4

As you add sufficient aileron to compensate for the wind, the airplane will want to turn in the direction of bank. Don't let this happen. Add enough opposite rudder to keep the airplane's longitudinal axis aligned with the runway centerline. In other words, if you add right aileron to lower the right wing and correct for the right crosswind, you must also add a little left rudder to keep the airplane from

CLASS 11: CROSSWIND LANDINGS

turning right. How much left (opposite) rudder do you add? Just enough so that the airplane's nose points straight down the runway. That's it.

From this position, fly the airplane all the way to the runway and begin a normal flare. Don't do anything different. As you begin the flare, the right wing will be low (right crosswind assumed here), and you'll touch down on the right, or upwind, wheel first. This is not only normal, it's expected. Airplanes are designed to do this while correcting for the crosswind. Of course, once you touch down on the upwind wheel, you'll want to lower the other wheel to the ground because it's going to go down on its own sooner or later. You won't find airplanes taxiing on one wheel. If you do, take a picture and send it to me. I gotta see this.

Combo Crab and Wing Low to Go

Do you see the basic difference between the crab and the wing-low method of correcting for crosswind? The wing-low method is a lot easier and requires a lot less skill to perform. It's also a more effective overall method for crosswind correction. Nevertheless, I combine both methods during crosswind landings.

I use the crab method while on final approach. Then, when I'm about 100 feet above the runway, I transition to the wing-low method. This prevents my passengers from feeling squished to the side of the airplane during a long sideslip.

There you have it. Crosswind landings aren't that tough. They do require practice, and I want you to get your share. Practice this on your own time, then meet me back here for the next ground school section.

CLASS 12: VOR NAVIGATION

Have you ever been so lost in your car that you actually considered pulling into a used car lot, selling the car, and using the money to purchase a new identity? If so, you were really lost. Getting unlost is easy, especially in a car. You simply drive into a gas station and ask for directions. You can't do that in an airplane. It attracts way too much attention, even if you buy gas and check the oil. Fortunately, you don't need to worry about getting lost in an airplane if you know how to use a little navigational device known as a VOR, which stands for Very high frequency Omnidirectional Range.

The Big Picture

VOR navigation requires two things: airborne VOR equipment, like that shown in Figure 12-1, and a ground transmitting station, which, from an altitude of several thousand feet, looks like an itty-bitty taco stand.



Figure 12-1 A-VOR receiver; B-VOR display.

The ground transmitter produces 360 electronic courses, each of which runs through the center of the station, as depicted in Figure 12-2. Each course is aligned with a specific degree on the compass, with 0 degrees pointing north, 90 degrees pointing east, 270 degrees pointing west, and so on. Using your airborne VOR equipment, you can navigate on any one of these 360 courses while going directly to or from a VOR station.

CLASS 12: VOR NAVIGATION

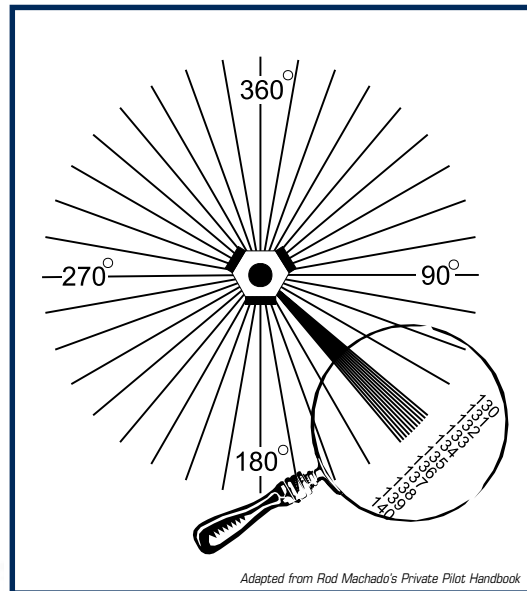


Figure 12-2 VOR radials

Of course, navigating to or from a VOR station does no good unless you know where that station is. Fortunately, pilots always fly with aeronautical sectional charts (Figure 12-3), which depict the locations of VOR stations. The VOR station (position 1) is located in the middle of the compass rose, which has

small markings every 5 degrees, larger markings every 10 degrees, and numbers every 30 degrees.

A box in the vicinity of the compass rose lists the name, Morse code identification, and frequency of the VOR ground station (position 2). In Figure 12-3, the VOR frequency is 112.3. Don't worry about the "CH 70." That's the frequency for military pilots and has nothing to do with cable TV.

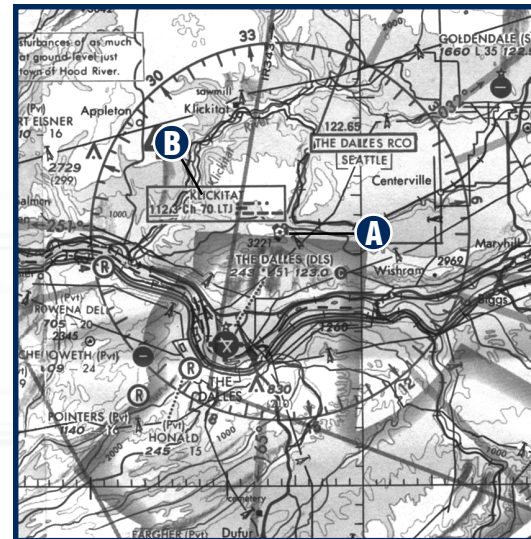


Figure 12-3

CLASS 12: VOR NAVIGATION

Your VOR Equipment

Most airplanes have one or more VOR receivers on board; each one is connected to a VOR display that looks similar to the one shown in Figure 12-4. When pilots refer to “the VOR in their airplane,” they are usually talking about the display, which consists of five main components:

- An index at the top of the display which points to the selected course.
- A vertical needle (also known as a course deviation indicator, or CDI) that swings right or left.
- A flag (or ambiguity indicator) in the form of a triangle that points up or down or a red-and-white striped flag. (A triangle pointing up represents a “TO” indication; a triangle pointing down represents a “FROM” indication, and a red-and-white striped flag represents an “OFF” indication. In this ground school session, I’ll use the words TO, FROM, and OFF to represent these three flag indications.)

- An omni bearing selector (OBS). This is the knob you turn to select a course.
- A circular, moveable compass card, which is adjusted by rotating the OBS. (Rotating the OBS causes a different course value to move to the index.)

How to Navigate using VOR

To navigate by VOR, you must first tune and identify the VOR station on which you want to navigate. With the appropriate frequency in the navigation receiver, you’re ready to select a course to fly (a highway in the sky).

Rotating the OBS and placing a specific number above the index (Figure 12-4) allows you to select any one of the VOR station’s 360 flyable courses.

CLASS 12: VOR NAVIGATION

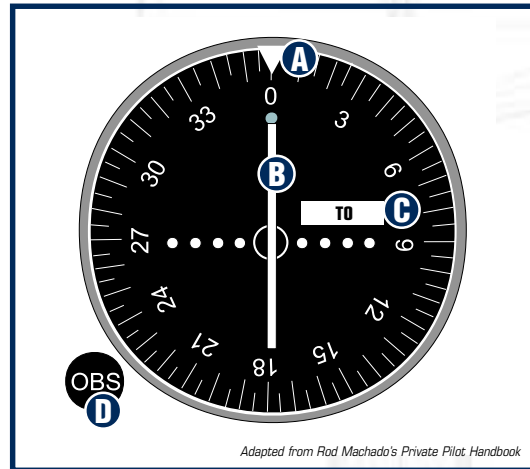


Figure 12-4 A-Index, B-CDI, C-Flag, D-OBS Knob

Let's suppose you select 360 degrees (or 0 degrees—they're the same thing) using the OBS. Your VOR display now automatically orients itself to show you where the 360-degree course is located relative to your airplane. As you can see, the 360-degree course runs completely through the VOR in a direction of 360 degrees. If you had selected the 270-degree course, your VOR display would orient itself to the 270-degree course, as shown in Figure 12-5B. Selecting 030 degrees using the

OBS orients the display to the course shown in Figure 12-5C. Selecting 240 degrees orients the display to the course shown in Figure 12-5D.

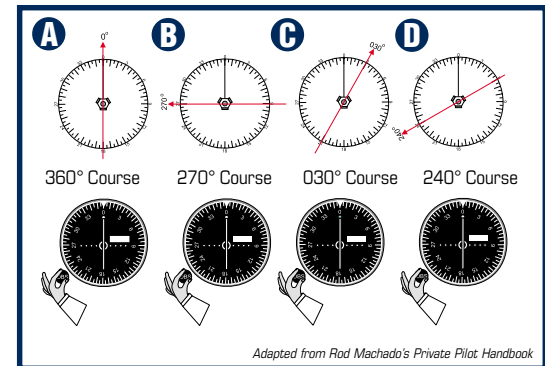


Figure 12-5

When operating Flight Simulator, be aware that the VOR's course selector knob rotates. Place your cursor near it, and when a plus sign (+) or minus sign (-) comes into view, select a specific course by clicking the mouse button.

Let's say that you've selected the 360-degree course (360 is shown above the index). To fly this course, you'd turn to a

CLASS 12: VOR NAVIGATION

direction of 360 degrees on the heading indicator. Assuming you've done this, the VOR indicator should show a centered needle with a TO flag (upward-pointing triangle) indication, as shown in Figure 12-6A.

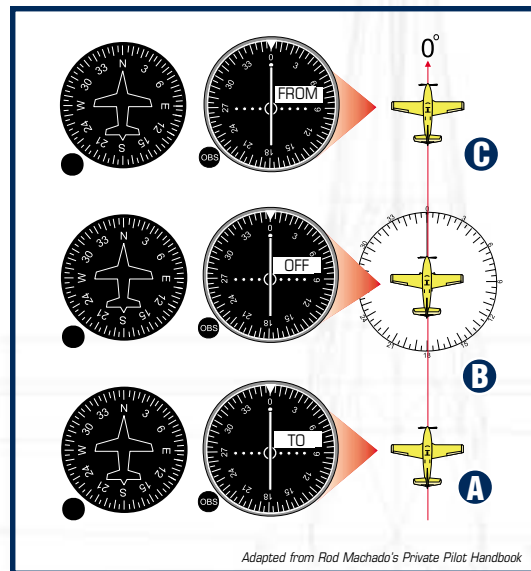


Figure 12-6

When you are directly over the station (Figure 12-6B), the flag reads OFF (red-and-white stripes), indicating that you're neither going to nor from the VOR at the

time. Simply stated, if the airplane is headed in the direction of the selected course and the needle is centered, the TO or FROM flag tells you if you're going to or from the VOR station.

As you fly along the selected course, the TO flag automatically changes to a FROM flag (downward-pointing triangle) as you pass the VOR station (Figure 12-6C).

So what happens if you are flying the correct heading and your VOR needle is not perfectly centered? That means you aren't yet aligned with the correct course. Figure 12-7 shows several airplanes and their respective VOR indications. Airplane A is heading 360 degrees (the direction of the selected course). Its VOR display shows a right needle with a TO indication. This means that the selected course is to the right, and, if Airplane A was on the course, it would be headed directly to the station. Airplane A must turn to the right to intercept the selected course. So must Airplanes C and E. Airplanes B, D, and F must turn left to intercept the course. Notice that when you are abeam (90

CLASS 12: VOR NAVIGATION

degrees to the side of the station, the flag shows OFF. No, this doesn't mean you're off course. It means that you are momentarily neither going to nor from the station. Remember, the needle leaning one direction or the other is telling you to turn that way.

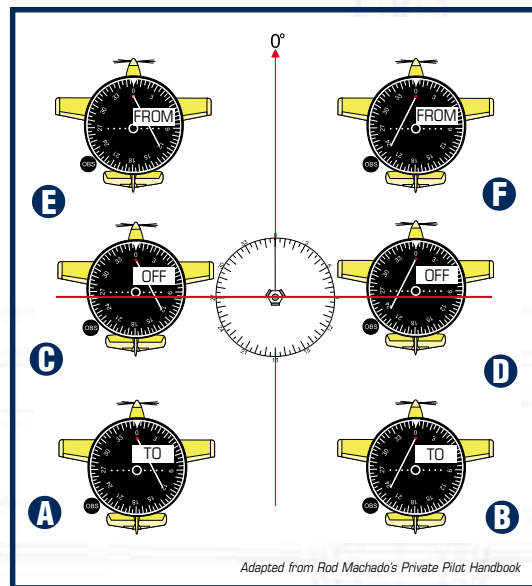


Figure 12-7

Intercepting and Tracking a VOR Course

Let's assume you want to depart Whatzitz Airport (and fly the 030-degree course to and beyond the VOR, as shown in Figure 12-8). (To be precise, degree values less than 100 are shown with a 0 in front of them. This prevents pilots from thinking that a value of 30 is 300 degrees. We pronounce 030 as "zero-three-zero." Say it like this, and you'll sound like an experienced airline captain.) Your destination is Yazoo Airport, which lies on the 030-degree course from the Rodster VOR.

CLASS 12: VOR NAVIGATION

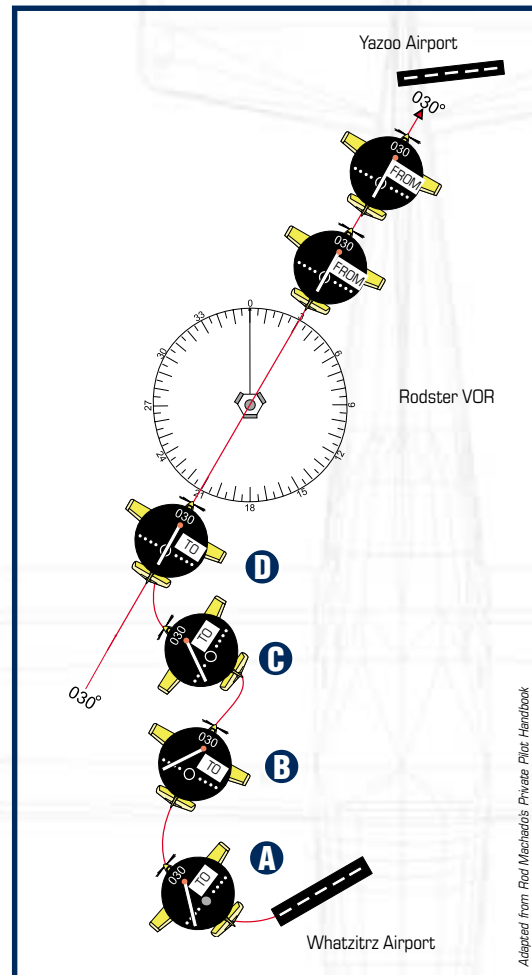


Figure 12-8

With your OBS set to 030, you depart Whatzitrz. The VOR display shows a left needle with a TO indication. A right or left needle indication doesn't tell you on which side of the selected course the airplane is located. To determine this, you must physically point the airplane in the direction of the selected course (or at least imagine yourself pointed in this direction). Why? The VOR needle and flag indications are completely independent of the airplane's heading.

I can't emphasize this point enough: VORs don't know which way your airplane is heading. That's because the airborne VOR display is programmed to think of itself as always pointing in the direction of the selected course. The display only knows if it's to the right or left of the selected course and whether that course will take it to or from the station.

Obviously, the 030-degree course is not to the left of the airplane. But if you turn the airplane to the direction of the selected course (030 degrees), then the needle and the flag properly orient you to that. Now, and only now, can the needle

CLASS 12: VOR NAVIGATION

be said to tell you that the selected course is physically to the left of the airplane. The TO/FROM flag tells you that once you're on the course and heading in a direction of 030 degrees, you'll be going directly to the VOR station (we'll assume there's no wind to blow you off course in this example).

I know there's a question burning in your mind: If you must turn to the left to intercept the 030-degree course, how many degrees to the left should you turn? The answer is more than 0 degrees and less than 90 degrees. It all depends on how fast you want to intercept. For practical purposes, if the VOR needle is fully deflected, you won't necessarily know if the selected course is 1 mile away or 100 miles away. In these situations, your objective should be to get on the course as quickly as possible; therefore, intercept at a 90-degree angle. Ask yourself, what heading is 90 degrees to the left of 030 degrees? Just look at the compass and count 90 degrees to the left of the selected course (Figure 12-10). Flying a heading of 300 degrees (this is perpendicular to the selected course) allows you to intercept in the shortest time.

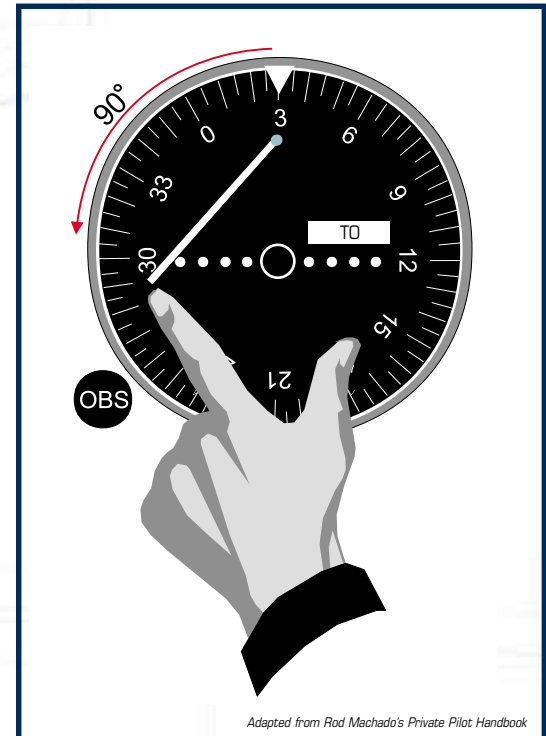


Figure 12-9

Looking back at Figure 12-8, Airplane B must turn to the left to intercept the 030-degree course. How many degrees to the left should it turn? The answer is more than 0 degrees and less than 90

CLASS 12: VOR NAVIGATION

degrees. If we wanted to intercept the course in the shortest possible time, we'd turn to a heading of 300 degrees (this is a perpendicular heading to the selected course), as shown by Airplane C in Figure 12-8.

Don't worry if you can't do this precisely at first. How quickly the needle centers depends on how close you are to the station. A little bit of experience will teach you to estimate the rate at which the needle approaches the center and how soon to begin your turn on the course heading.

Flying from the VOR on a Selected Course

Let's make VOR usage even more practical. Suppose you are airborne in the vicinity of Ulost Airport (Airplane A in Figure 12-10) and want to fly to Wongway Airport. Since this is a VOR lesson, let's use the VOR to find Wongway. Ask yourself, "What's the best way to get to the Bigfoot VOR?" It's reasonable to assume you're always on some course that goes to a VOR. But how do you know which course this is? Here's how.

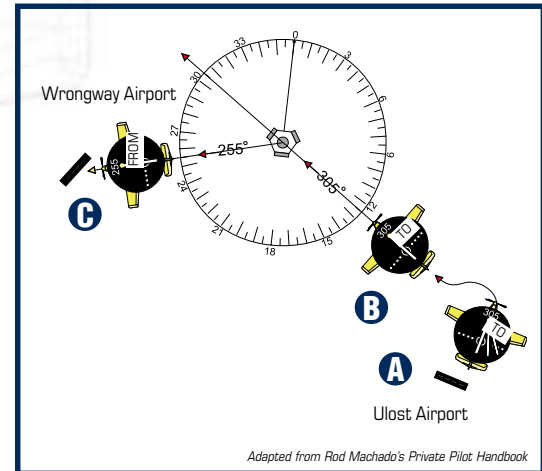


Figure 12-10

Tune in the Bigfoot VOR frequency on your navigational radio, and rotate the OBS until you get a TO flag indication with a centered needle, as shown by Airplane B in Figure 12-10. Look up at the index to see what course is selected. In this instance, you're on the 305-degree course to the Bigfoot VOR. Turn to a heading of 305 degrees on your heading indicator, and fly that course to the VOR, as shown by Airplane B. Easy, eh?

CLASS 12: VOR NAVIGATION

As you approach the VOR, ask yourself what course runs from the center of the station through Wongway Airport. Draw a line (or eyeball the value) to determine this course. It appears that the 255-degree course runs from the VOR through Wongway Airport. Therefore, when you're over the station, turn the airplane in a direction of 255 degrees, then rotate the OBS to 255 degrees. Now your VOR display is set to track the 255-degree course from the airport to Wongway Airport, as shown by Airplane C.

Wind Correction while Tracking a VOR Course

I hope you aren't blown away by all this. But then again, how could you be blown away since I haven't talked about wind? Until now, I've assumed a wind-free environment, but this seldom exists in the real world. Let's learn how to correct for wind when navigating using VOR.

Wind correction is broken down into three components:

- Identifying the effect of wind on the airplane

- Reintercepting the course
- Applying a wind correction

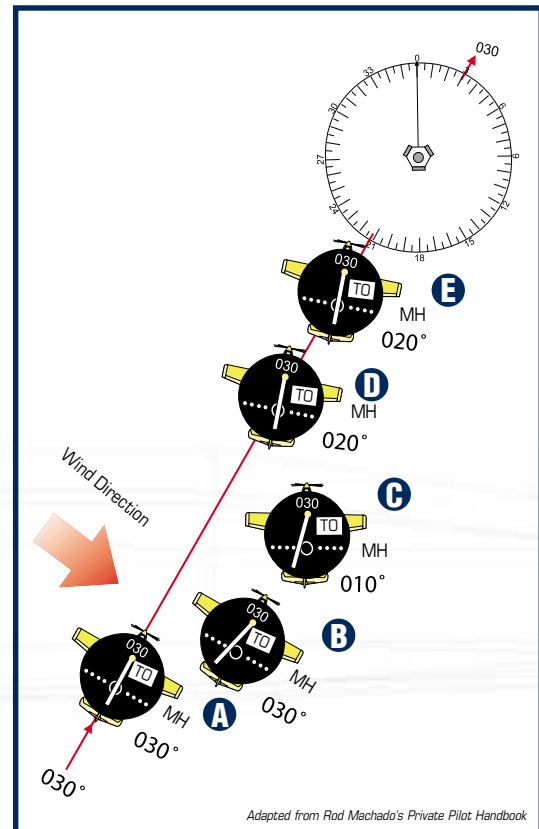


Figure 12-11

CLASS 12: VOR NAVIGATION

Here's how this works:

1. Identify the effect of wind. Airplane A in Figure 12-11 has just intercepted the 030-degree course to the VOR. Under a no-wind condition, Airplane A could hold a 030-degree heading and fly to the VOR with a centered needle. With a little wind, however, Airplane A is sure to drift off course. Determining wind direction and making the proper correction is the first step to successful navigation.

To determine the effect of wind on the airplane, head the airplane in the direction of the selected course (030 degrees in this example). Now you must wait a bit. If there is no wind, the needle should stay centered (or nearly so). If a crosswind exists, the needle will eventually show a deflection, as depicted by Airplane B. How much of a needle deflection should you allow before reintercepting the course? Perhaps the best advice in this instance is to let the needle move just a little (perhaps less than one dot on the VOR's display), and then make a correction.

2. Reintercept the course. If the needle moves to the left, then the selected course is to the left, as shown by Airplane B. The airplane was blown to the right of the course (implying the crosswind is from your left). Once you've identified the wind direction, you need to get back on course before applying a wind correction. You can get back on course by intercepting at a 20-degree angle, as shown by Airplane C in Figure 12-11 (strong winds sometimes require that you reintercept at a 30- to 40-degree angle).
3. Apply a wind correction. Once reestablished on course, the third step is to apply a wind correction. You must compensate for the wind's push by heading the airplane into the wind. How much? That depends on several variables, one of which is the wind's speed and direction. Actually, these variables don't really matter all that much. Just start with a 10-degree wind correction angle and see what happens. It's just like going to the movies. You never quite know how

CLASS 12: VOR NAVIGATION

good or bad the film might be, so you try it (although the last movie I watched was so bad that I walked out. Unfortunately, it was on TV at the time, and I walked out of my own house). Once you're on course, turn the airplane so it's pointed 10 degrees into the wind (which means it's now heading 020 degrees, as shown by Airplane D in Figure 12-11). Be patient, Grasshopper. Wait to see what happens.

As you can see, Airplane E is tracking directly to the VOR station on the 030-degree course. The needle hasn't moved. Congratulations! You've successfully corrected for wind. And you're darn lucky if you, or for that matter any experienced pilot, can find the proper wind-correction angle on the first attempt. Realistically, you'll probably need to make a minimum of two attempts at determining a wind-correction angle before finding the proper value. The same wind-correction principle applies when tracking from the VOR on a specific course.

You did a great job! You're on your way to becoming a high priest of VOR tracking, master of all meteorological forces, and reigning king of all airway navigation. You'll be required to walk around the airport in white robes. Pilots from all over will come seeking your guidance. Wow, TV shows! Live appearances! Think of the possibilities. At the very least, you'll get to your destination with ease.

It's time for you to practice VOR navigation in the Private Pilot Lesson. Next, read the ATC Handbook and take the ATC Lesson. Finally, take the Private Pilot Checkride.

CLASS 12: VOR NAVIGATION

VORs and Airborne Freeways

Until now I've referred to all VOR routes as courses and for good reason, too. It makes the whole process easier to understand. In order to do advanced things, such as fly instrument approaches, you need to think about tracking to and from a VOR on a specific radial instead of a specific course. While pilots speak of traveling to and from a VOR on a specific course, they can also speak of traveling to and from the VOR on any one of its 360-degree radials.

Let's begin our discussion with a recollection of your last car trip when you drove through a small town. Let's also say the freeway pointed due north as it passed straight through this town, as shown in Figure 12-12A. While entering and leaving the town, your car pointed north (360 degrees), in the same direction as the freeway. If the portion of the freeway exiting this town had a different name than the portion entering the town, would this affect the direction your car pointed while passing through town? Of course not. So let's call the portion of the freeway exiting the town to the south Freeway 180 and the portion exiting to the north Freeway 360, as shown in Figure 12-12B. Now we can say that we went to town on Freeway 180 and exited on Freeway 360. Your direction never changed despite giving the freeway different names.

CLASS 12: VOR NAVIGATION

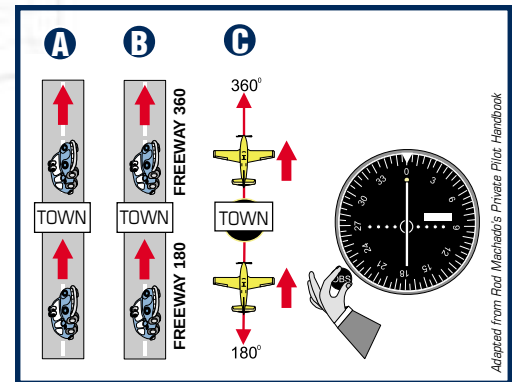


Figure 12-12

Navigation by VOR is basically the same, as shown by Figure 12-12C. If you're headed northbound to the Town VOR, you travel inbound on the 180-degree radial and outbound on the 360-degree radial. Either way, your airborne freeway points in a direction of 360 degrees, just like the ground-bound freeway. Referring to a single freeway by radials going to and from a VOR station is sometimes awkward. But this is the way instrument pilots are required to think of VOR navigation. Therefore, when you're asked to intercept and track to a VOR station on the 180 radial, you must think of setting your OBS to 360 degrees (or the 180-degree reciprocal of the radial on which you'll track to the station). Until you start to fly instrument approaches, just think of all VOR routes as courses.

CLASS 13: STEP 1 OF THE INSTRUMENT SCAN

Attitude, Power, and Trim

During most of the past classes, you've seen what flying is like when looking at the earth's horizon through the windscreen. Suppose I took that away from you. No, not the windscreen. I mean your outside visual references. That's what would happen if you flew into a cloud. In case you don't know this, you can't see very far when you're inside a cloud, which means it's unlikely that you'd be able to see the earth's horizon. Without visual references, you'd need to rely on the airplane's instruments to maneuver. That's what the next three classes are about.

I plan to show you a three-step process for scanning your flight instruments. It's the same process I use when preparing students for their instrument rating (a license allowing them to fly inside clouds). If you take the time to master each step, you'll acquire skills similar to those possessed by airline pilots. The only difference is that you won't have 150 to

400 people sitting behind you watching every move you make. First, let's make sure you understand what instrument scan actually means.

The Scan Plan

When pilots talk about scan, they don't mean CAT scan (which my cat doesn't like) or brain scan (which you'll need if you dent a lot of airplanes). They're talking about scanning the six flight instruments on the airplane's panel, as shown in Figure 13-1. Scanning is not just moving your head quickly enough to cause your eyes to rattle in their sockets like the last breath mint in the plastic box. It's a strategic process of knowing what instrument to look at, when to look at it, and what to do after you look at it. That's why I've broken the scan process down into three easy steps. All three steps are shown below, but I want you to master each step one at a time before combining them into a smooth, continuous process.

CLASS 13: STEP 1 OF THE INSTRUMENT SCAN



Figure 13-1

The Three Steps

Here are the steps in the order they should be performed:

STEP 1: Select attitude, power, and trim.

STEP 2: Radial-scan the primary instruments.

STEP 3: Trim using the VSI, and monitor-scan the Big-6 instruments.

These three steps are executed in sequence every time you make a major attitude change. For instance, if you're in

straight-and-level flight and want to enter a climb, that's a major attitude change. Transitioning from a straight climb to a climbing turn is also a major attitude change. Essentially, any combination of the basic flight maneuvers involves a major attitude change. All three steps in sequence should take approximately 15 to 20 seconds to complete. In this class, you'll work on Step 1, followed by Step 2 and Step 3 in the next two classes. Master each step, and you'll master flight by reference to instruments.

The Most Important Instrument

Step 1 of the instrument scan involves one of the most important instruments on the airplane—the attitude indicator (called AI from now on). When you select the attitude in Step 1, you are looking at the AI and nothing else. You can afford to do this because the AI provides both pitch and bank information. Other instruments in the group give you a form of either pitch or bank information, but not both. This is why the AI is so valuable. Before we talk about Step 1, however, you need to understand something known as a wing leveling-and-pitch reflex.

CLASS 13: STEP 1 OF THE INSTRUMENT SCAN

The wing leveling-and-pitch reflex refers to the skills necessary to help maintain any desired attitude. Maintaining a specific attitude isn't an easy thing to do. Pilots are often distracted from their scan, and turbulence frequently perturbs the airplane, both of which may induce a bank, resulting in an unwanted turn. Skilled pilots immediately correct this unwanted pitch and bank by reflex. Without thinking about it, they reflexively move the joystick and return the airplane to the desired attitude. Unless you've practiced doing this, you'll have to think about it before reacting. While a slow reflex may work if you're flying a blimp, it won't work in an airplane.

You'll get a chance to develop your wing leveling-and-pitch reflex in the Interactive Lessons. Don't rush through this exercise. I can't express enough how important it is. I spend several hours with students in airplanes making sure they know which way to move the joystick to level the wings or maintain the desired pitch. If you feel you've mastered these reflexes (and still have some feeling left in your arms), then move on to Step 1 of the three-step scan.

Step 1 of the Scan

Step 1 requires you to select the attitude, power, and trim conditions for the desired attitude. For instance, if you're in straight-and-level flight (Figure 13-2) and want to climb (this is a major attitude change), you'll need to select a climb attitude, apply climb power, and then trim for this condition. Do this by focusing entirely on the AI.



Figure 13-2

From your previous experience, select the attitude that gives you the flight conditions desired. You still remember

CLASS 13: STEP 1 OF THE INSTRUMENT SCAN

these attitudes from the previous lessons, don't you? If not, now may be a good time to review them. Figure 13-3 shows the approximate pitch required to climb at 80 knots with full power (13 degrees nose-up).

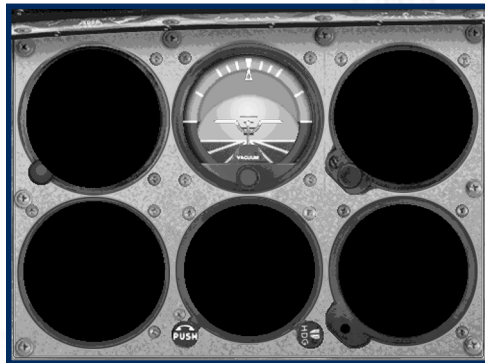


Figure 13-3

Here's how we'd complete the sequence according to Step 1 when entering a climb from straight-and-level flight:

1. Pitch the airplane up to 13 degrees. You can't be sure that this will give you exactly 80 knots, but that's okay for now. You just want to put the airplane in the approximate attitude. We'll worry about the details later.
2. After pitching up, apply climb power (2550 RPM). (Don't apply climb power until the airplane begins pitching up. The pitch-up attitude puts an aerodynamic load on the propeller and prevents RPM overspeed as you apply power.)
3. Apply trim to maintain climb attitude. (You're interested in a rough approximation of trim here. The final trim is applied in Step 3 of the three-step scan.)

Excellent! Muy bien. Now let's examine how we'd apply Step 1 of the scan as we make a major attitude change and return to straight-and-level flight from a climb.

Straight-and-Level Flight from a Climb, Entering

If you're in a climb, here's how you would return to straight-and-level flight using Step 1 of our instrument scan.

1. Pitch the airplane forward to the attitude for straight-and-level flight (Figure 13-2). You can't be sure you're in precise straight-and-level flight, but that's still okay for now.

CLASS 13: STEP 1 OF THE INSTRUMENT SCAN

2. Wait approximately 10 seconds, then reduce power to a cruise setting of 2300 RPM. (Why wait 10 seconds? Because you want the airplane to accelerate quickly to cruise speed before making a power reduction. In the next class, you'll wait until

reaching a cruise airspeed of 100 or more knots before reducing power. Since you can't see the airspeed, use 10 seconds for now.)

3. Once the power is reduced, apply trim to maintain the attitude for straight-and-level flight.

Now let's examine how we'd handle entering a descent from straight-and-level flight using Step 1. The important thing to know here is the proper attitude when descending. Descents are typically done at airspeeds higher than that used for climbing. So let's use a one-half-degree pitch-down attitude, as shown in Figure 13-4. This will give you a descent at approximately 100 knots. Remember the sequence: attitude, power, and trim. Here's how it should go.



Figure 13-4

Descent from Straight-and-Level Flight, Entering

1. Select the proper attitude for the descent (Figure 13-4).
2. Immediately reduce power to flight idle. (It's considered good form to make the attitude and power change at the same time. Reducing power results in the nose automatically pitching forward on its own, which makes it easier to establish the nose-down attitude. Lowering the nose with power on results in an increase in airspeed, perhaps beyond that which you want.)

CLASS 13: STEP 1 OF THE INSTRUMENT SCAN

3. Trim to maintain the desired nose-down pitch attitude.

Next, let's examine how we'd enter straight-and-level flight from a descent. Remember the sequence: attitude, power, and trim.

Straight-and-Level Flight from a Descent, Entering

1. Select the attitude for straight-and-level flight (Figure 13-2).
2. Add power to cruise RPM (2300). If you wait too long to add power, the airspeed will decrease. That's why it's usually good form to start increasing power as soon as the airplane approaches a level flight attitude.
3. Trim to maintain the desired attitude.

This was an important ground school class. It's often the little things that give instrument pilots a difficult time, such as knowing how and when to change power. Granted, this may not be exciting, but it is worthwhile to understand. Now let's examine how we'd enter a turn from straight-and-level flight (another major attitude change) using Step 1 of our instrument scan.

Climbing and Descending Turns, Entering

In previous classes, you learned that turns were made at 20 to 30 degrees of bank. This is appropriate for instrument flying, too. What you don't want to do is make turns in excess of 30 degrees of bank. Why? Turning too steeply increases a pilot's workload while flying under instrument conditions. Instrument flying is hard work, and the last thing a pilot needs is to struggle with the aerodynamic forces associated with steep turns. Let's agree to use 20 degrees of bank for all turns while flying instruments. Later, you'll learn advanced turning concepts, such as standard rate turns.

Since I know you're already skilled at turns, let's examine how we'd use Step 1 of our instrument scan to combine the turn and the climb entry during this major attitude change. This is just like a fancy dance step in which moves are combined, but no one's toes are jeopardized. The secret is to enter a 20-degree bank turn while simultaneously pitching to climb attitude. Here's how it's done.

CLASS 13: STEP 1 OF THE INSTRUMENT SCAN

Entering a Climbing Turn

1. Roll into a 20-degree bank turn to the right, and simultaneously pitch up to climb attitude (Figure 13-5).
2. After pitching up, apply climb power (Full Power).
3. Trim to maintain climb attitude.

Now let's examine how we'd enter a left-descending turn using Step 1.



Figure 13-5

Entering a Left-Descending Turn

1. Select the attitude for a left-descending turn (Figure 13-6).
2. Simultaneously reduce power to flight idle.
3. Trim to maintain this attitude.



Figure 13-6

Remember, you've been practicing Step 1 of a three-step instrument scan. Once the attitude, power, and trim conditions are established, you're ready to move on to Step 2. Step 2 allows you to fine-tune the attitude selection you made in Step 1. But first, proceed to the Interactive Lesson and practice these maneuvers before beginning the next class.

CLASS 14: STEP 2 OF THE INSTRUMENT SCAN

Radial-Scanning the Primary Instruments

Step 1, Step 2, Step 3: Doesn't this sound like a Fred Astaire introductory dance lesson? Well, instrument scan is best taught and understood by easily managed steps. In this sense, your dance partner is the instrument panel, and your eyes dance from instrument to instrument in an organized way. You've learned Step 1 of the three-step scan—now on to Step 2.

Step 1 allowed you to place the airplane in any attitude solely by reference to the attitude indicator (AI). Using the AI as your only means of attitude control, however, is like using a thermonuclear weapon to kill fleas in your apartment. It works, but lacks the precision your neighbors have come to expect in a bug bomb. As an instrument flyer, you need precise control of headings, altitudes, and airspeeds. Once you've selected a new attitude in Step 1, you'll proceed to Step 2, where you'll radial-scan the primary instruments and fine-tune the attitude selected in Step 1.

Here are the three steps for your review. Remember, all three steps are done in sequence every time you make a major attitude change. In total, all three steps take from 15 to 20 seconds to complete.

STEP 1: Select attitude, power, and trim.

STEP 2: Radial-scan the primary instruments.

STEP 3: Trim using the VSI, and monitor scan the Big-6 instruments.

The purpose of Step 2 is to look at one or more flight instruments and then make any necessary changes in pitch, bank, or power to obtain the flight attitude desired. This, in turn, allows you to obtain the precise heading, airspeed, and altitude desired. The term radial-scan signifies that your scan starts at the AI, goes to a primary instrument on the panel, and then returns to the AI. The scan pattern is out and then back along the same path. Think of the path your eyes make as they start from the center of a bicycle's wheel and follow a spoke radiating outward and inward, as shown in Figure 14-1.

CLASS 14: STEP 2 OF THE INSTRUMENT SCAN

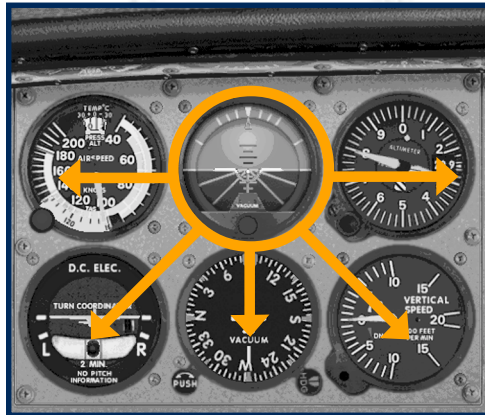


Figure 14-1

Anything that's primary is important. And primary instruments give you the most important information for precise control of pitch, bank, and power. Each attitude you select uses three primary instruments: one for pitch, one for bank, and one for power. But how do you know which instruments these are? After all, you have several to choose from. To answer that question, let's go for a hamburger.

Instrument Names

When you order food from the Hamburger Palace, the server pushes a button with a picture on it of the item you selected. Order a soda, and he pushes a button with a soda on it. This neat visual method frees up the server's mind to think about more important things, such as philosophy, ethics, and an alternate proof to Fermat's last theorem. Of course, if you say, "Beautiful weather," the server might say, "I'm sorry, I don't have that button." Let's use a similar labeling system to identify the primary instruments on your panel.

I'd like you to place the labels shown in Figure 14-2 directly onto your computer screen under each instrument shown (we won't label the VSI for now). Use a small quarter-inch strip off the sticky end of one of those yellow sticky notes. Don't use labels with permanent adhesives (there's always a job open for you at that burger joint if you do!).

CLASS 14: STEP 2 OF THE INSTRUMENT SCAN

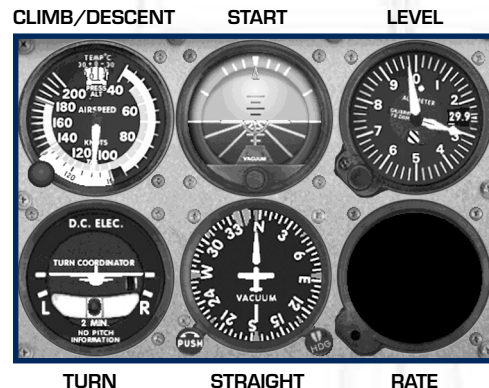


Figure 14-2

Identifying Primary Instruments

Figure 14-2 identifies the primary instruments for any given flight condition. Assume that you've just selected the attitude for straight-and-level flight. Which primary instruments should you radial-scan? Look at the panel and find those instruments labeled straight (heading indicator) and level (altimeter). The heading indicator helps you fly straight; the altimeter helps you fly level; and the tachometer shows the power setting selected. In other words, you can fine-tune the attitude for straight-and-level flight by scanning only these three instruments. Easy, huh?

Suppose you've placed the airplane in the attitude for a straight climb (or descent). Which primary instruments should you radial-scan? Find the instruments labeled straight (heading indicator) and climb (airspeed indicator). The heading indicator helps you fly straight; the airspeed indicator helps you determine the proper pitch for a climb (or a descent); and the tachometer shows the power setting selected.

Finally, let's suppose you placed the airplane in the attitude for a level turn. Which primary instruments should you radial-scan? Find the instruments labeled level (altimeter) and turn (turn coordinator). The altimeter helps you fly level; the turn coordinator helps determine the amount of bank required for the desired turn (you'll see how shortly); and the tachometer shows the power setting selected.

Now you know how to determine which instruments to scan for any condition of flight. Next, you want to radial-scan the primary instruments and observe their indication or detect needle movement.

CLASS 14: STEP 2 OF THE INSTRUMENT SCAN

Then, return to the AI and make an attitude adjustment (if necessary) to stabilize the primary instrument. Let's examine how we'd do this with straight-and-level flight first. We'll assume that we've just entered straight-and-level flight from another attitude.

The Basics of Radial-Scanning

All but the primary instruments for straight-and-level flight are blackened out in Figure 14-3, the way they would be in real instrument training. We'll assume that you've just completed Step 1 and have placed the airplane in the attitude for straight-and-level flight. Begin Step 2 by radial-scanning the primary instruments and adjusting the attitude on the AI (if necessary) for precise straight-and-level flight. Before we continue with this discussion, let's talk a little more about radial-scanning.

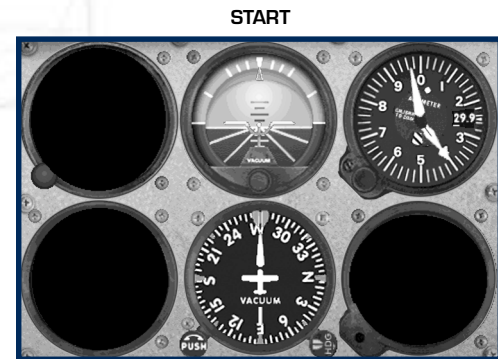


Figure 14-3

The AI has the word “start” over it since this is where all radial scanning begins. Like the hub of that bicycle wheel, your scan will start here and radiate outward to a primary instrument. You’ll spend about 1 to 2 seconds on the primary instrument while checking for any deviations or needle movement. Then, you’ll return to the AI and make corrections (if necessary) to stabilize the primary instrument.

CLASS 14: STEP 2 OF THE INSTRUMENT SCAN

Of course, you can radial-scan more than one instrument. To do so, you'd start at the AI, go to a primary instrument, and then return to the AI. From there, you'd go out to another primary instrument and return to the AI, repeating the process over again with any instrument desired, always returning to the AI.

For instance, in straight-and-level flight, you'll radial-scan the heading indicator (straight), the altimeter (level), and the tachometer (power). Starting at the AI, move down to the heading indicator. Look for any deviation from the desired heading. Return to the AI, and make a small change in bank (if necessary) that stops the heading change or returns the airplane to the appropriate heading. From there, move to the altimeter and look for any deviation from the desired altitude. Return to the AI, making a small pitch change (if necessary) that stops the needle or returns it to the appropriate position. The tachometer is radial-scanned last. Look at the tachometer and make a final adjustment in the setting (if necessary), then immediately return to the AI. Usually, there is no need to radial-scan the tachometer more than

once during a major attitude change. Now, start over with the heading indicator, repeating the radial-scan until both instruments (heading indicator and altimeter) indicate straight-and-level flight. Here's how the sequence should look.

Straight-and-Level Flight

1. Start at the AI, and radial-scan the heading indicator.
2. Return to the AI, and adjust the bank (if necessary) to maintain 270 degrees.
3. Radial-scan the altimeter.
4. Return to the AI, and adjust the pitch (if necessary) to maintain 4,000 feet.
5. Radial-scan the tachometer, and adjust the throttle position (if necessary) for a cruise RPM of 2300 (there's usually no need to radial-scan the tachometer again).
6. Keep radial-scanning the heading indicator and altimeter, making small attitude corrections, until the airplane is established in straight-and-level flight.

The secret to radial-scanning is to quickly scan each of the primary instruments at least once before spending additional

CLASS 14: STEP 2 OF THE INSTRUMENT SCAN

time radial-scanning any one instrument in particular. This allows you to determine how close the airplane is to the desired attitude and gives you an idea about how much work will be involved in stabilizing the airplane. Let's examine how we'd radial-scan the primary instruments in a straight climb.

A Straight Climb

Once again, all but the primary instruments for a straight climb are blackened out (Figure 14-4). Let's assume that you've just entered a climb straight ahead and are starting Step 2 of the three-step scan. You'll adjust the attitude on the AI for a precise climb at 80 knots on a heading of 270 degrees.

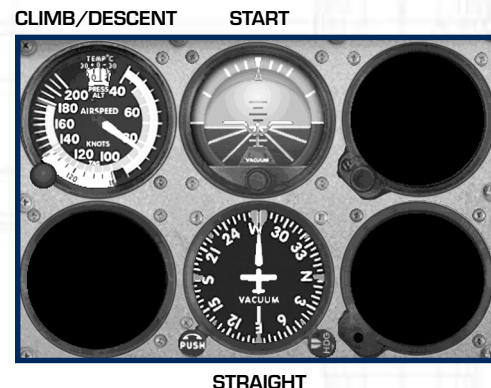


Figure 14-4

Here's the sequence you'd use to radial-scan the primary instruments.

1. Start at the AI, and radial-scan the heading indicator.
2. Return to the AI, and adjust the bank (if necessary) to maintain a heading of 270 degrees.
3. Radial-scan the airspeed indicator.
4. Return to the AI, and adjust the pitch (if necessary) to maintain 80 knots.
5. Radial-scan the tachometer (if necessary), and adjust the RPM to a climb value of 2400 (there's no need to radial-scan the tachometer again).
6. Keep radial-scanning the heading indicator and airspeed indicator, making small attitude corrections, until the airplane is established in a straight climb at 80 knots on a heading of 270 degrees.

There you have it. Knowing ahead of time what instruments to look at for precise control of your attitude takes the mystery out of flying instruments.

Now let's try Step 2 of our scan on a level flight turn.

CLASS 14: STEP 2 OF THE INSTRUMENT SCAN

A Level Flight Turn

All but the primary instruments for a level turn are blackened out (Figure 14-5).



Figure 14-5

Let's assume that you've just entered a level turn to the left at 4,000 feet and are starting Step 2. You should begin radial-scanning the primary instruments and adjust the attitude on the AI for a precise altitude of 4,000 feet and a standard rate turn.

Huh? What's a standard rate turn?

Standard rate turns allow the airplane to change headings at a rate of 3 degrees per second. In the previous class, I suggested you make turns at 20 degrees of bank. That's perfectly fine, but for greater precision, I want you to make them at a standard rate. You'll do this by adjusting the bank until the wing of the turn coordinator's airplane is on the second white index mark, as shown in Figure 14-5.

Now the airplane will change headings at precisely 3 degrees per second. A standard rate turn gives you a sense of how long it takes to complete a turn. After all, at 3 degrees per second, it takes two minutes to make a 360-degree turn and one minute to make a 180-degree turn. Here's the sequence you'd use to radial-scan the primary instruments.

1. Start at the AI, and radial-scan the altimeter.
2. Return to the AI, and adjust the pitch (if necessary) to maintain 4,000 feet.

CLASS 14: STEP 2 OF THE INSTRUMENT SCAN

3. Radial-scan the turn coordinator.
4. Return to the AI, and adjust the bank (if necessary) to maintain a standard rate turn.
5. Radial-scan the tachometer (if necessary), and adjust the RPM to a cruise value of 2300 (there's no need to radial-scan the tachometer again).
6. Keep radial-scanning the altimeter and turn coordinator, making small attitude corrections, until the airplane is established in level flight at 4,000 feet in a standard rate left turn.

If you've gotten this far, you'll soon be qualified to say, "Who's the greatest pilot... and why am I?" In our final example, we'll examine how to apply Step 2 to accomplish a right-descending turn.

A Power-Off, Right-Descending Turn

All but the primary instruments for a descending turn are blackened out (Figure 14-6). Let's assume that you've just entered a power-off right-descending

turn and are starting Step 2 of the three-step scan. Begin radial-scanning the primary instruments. Adjust the attitude on the AI for a precise descent at 100 knots in a standard rate turn.



Figure 14-6

Here's the sequence you'd use to radial-scan the primary instruments.

1. Start at the AI, and radial-scan the airspeed indicator.
2. Return to the AI, and adjust the pitch (if necessary) to maintain 100 knots.

CLASS 14: STEP 2 OF THE INSTRUMENT SCAN

3. Radial-scan the turn coordinator.
4. Return to the AI, and adjust the bank (if necessary) to maintain a standard rate turn. (There is no reason to radial-scan the tachometer since you've reduced the throttle to flight idle.)
5. Keep radial-scanning the airspeed indicator and the turn coordinator, making small attitude corrections, until the airplane is established in a standard rate descending turn to the right at 100 knots.

In our next class, we'll complete the final step of the three-step scan. This is where we'll wrap up all the hard work of establishing the airplane in a new attitude. We'll trim, sit back, and enjoy the new attitude we've selected—at least until we decide to make another major attitude change.

CLASS 15: STEP 3 OF THE INSTRUMENT SCAN

Trim using the VSI, and Monitor-Scan the Big-6 Instruments

By now, you know that instrument pilots are not folks who sit in airplanes and play piccolos or guitars. The closest they come to making music occurs as they follow a step-by-step instrument-scan procedure when making a major attitude change. So far, we've covered two of the three steps. Let's complete our instrument-scan procedure by studying the last step in the three-step scan.

Here are the three steps for your review. They're listed in the order you do them when making a major attitude change.

STEP 1: Select attitude, power, and trim.

STEP 2: Radial-scan the primary instruments.

STEP 3: Trim using the VSI, and monitor-scan the Big-6 instruments.

In Step 1, you made a major attitude change followed by Step 2, in which you fine-tuned the airplane's pitch, bank, and power. In Step 3, you'll offer a final twist of the trim so the airplane stays put, then you'll relax a bit and monitor-scan the six main flight instruments on your

panel (also known as the Big-6 instruments). Monitor-scanning is a more relaxed way of observing the flight instruments compared to the radial-scan of Step 2. Let's take a closer look at Step 3 of the scan.

Step 3 of the Scan

Your main objective in Step 3 is to make a final trim adjustment by referencing the vertical speed indicator (VSI). The VSI is sensitive to small pitch changes and will quickly indicate any deviation away from the desired attitude. Additionally, the length of the VSI's needle makes it easier to detect vertical movement.

The secret of the final trim is to look for a constant VSI indication. When leveling off, trim so that the VSI needle indicates a zero rate of climb. Don't whip the trim wheel (or button) around like you're spinning a merry-go-round and trying to make your little brother sick. Give the trim wheel a slight twist, and then ease up on any control pressures you might be applying. Watch the VSI's needle. If it moves up or down, apply nose-down or nose-up trim, respectively, to stop the needle's movement.

CLASS 15: STEP 3 OF THE INSTRUMENT SCAN

There's never any reason to completely let go of the controls to see which way an out-of-trim airplane moves. This causes pilots more heartaches than it's worth. By letting go of the controls instead of easing off a little on control pressures, an untrimmed airplane could rapidly deviate from the planned flight attitude, depending on just how out of trim it was. Now, you must return the airplane to its previous flight condition before you retrim. It's much easier to relax the control pressure, observe the beginning of any VSI needle movement, and make a corresponding change in the trim. Small adjustments in trim can now be made without having to recapture a runaway airplane.

Trimming for a climb or descent is done in a similar manner to trimming for level flight. Relax control pressure, and watch for a constant VSI needle indication. Suppose the needle indicates a specific climb rate. If you relax control pressure and the needle moves, then the airplane needs trimming. Apply nose-up or nose-down trim as appropriate to stabilize the

airplane at the previous climb rate (or descent rate). It may take two or three adjustments of trim to find a setting that works, but that's okay. You've got the time. It's not as if you're going anywhere, are you?

Also, keep in mind that it's difficult to trim an airplane perfectly. Even if you're a high priest (or priestess) of trim, an airplane can still wander up or down a few hundred feet. There's not much you can do about this outside of making small, manual pitch corrections. Airplanes are not all created equal. A little dent here, a little extra weight there—all of these have a subtle effect on aerodynamic performance, which prevents an airplane from being perfectly trimmed.

Monitor Scanning

After the final trim adjustments are made, the six main panel instruments (Figure 15-1) are monitor-scanned. This is often done in a clockwise fashion, going from the top row to the bottom row of instruments. Actually, you can select any particular pattern of eye movement that is comfortable to you.

CLASS 15: STEP 3 OF THE INSTRUMENT SCAN

The objective is to monitor deviations from the established attitude. If you notice a deviation, make a small adjustment on the attitude indicator to maintain the desired flight conditions.



Figure 15-1

Monitor scanning is the condition in which you'll spend most of your time while on instruments. Step 3, therefore, is performed continuously until a new flight attitude is desired (thus requiring a major change in attitude). All three steps of the scan procedure are repeated again when making this major attitude change.

The first two steps of the three-step scan typically take 5 to 15 seconds to complete. There will be instances in which you might have completed Step 2 of the scan and might not be able to move on to Step 3. For example, in turbulence or when you're on an instrument approach, you may find yourself obliged to rapidly radial-scan the primary instruments to maintain precise control of the airplane. Remember, radial scanning is a lot of work: physically, intellectually and emotionally. It is possible to radial-scan all the instruments on the panel, but this is usually unnecessary and can become tiresome. Radial-scan only those (primary) instruments necessary to control the airplane.

A Tip from the Professionals

Over the years, some professionals have reported a rather unusual method of detecting instrument deviation once the airplane's attitude has been established and the aircraft trimmed. These pilots focus their vision in the center of the panel just underneath the attitude indicator. Relying upon only their peripheral vision, they watch for any instrument

CLASS 15: STEP 3 OF THE INSTRUMENT SCAN

movement. In much the same way a speed reader is taught to take in three or four words at a glance, instrument pilots can absorb information from clusters of instruments at a single glance. Developing peripheral vision takes practice, but it does seem to represent the higher art of instrument flying. Until then, when Step 3 of the scan is completed, keep your eyes moving around the panel while looking for attitude deviations.

Subtle Secrets

The VSI, once mastered, provides additional useful information for the precise control of an aircraft. Most pilots also find the VSI useful for helping maintain level flight within the 10- to 20-foot range. Sometimes, it's easier to use the VSI to identify trends away from level flight because of the large swing arc and greater sensitivity of its needle. Taking time to learn to fly the VSI with precision pays off handsomely.

There are many boring things to do in life, but instrument flying isn't one of them. The art of flying instruments is a challenging test of your mettle. Instrument flying offers you the opportunity to master the airplane and yourself. Perhaps this is why most instrument pilots are so happy. They realize the scope of their accomplishment. I should warn you, however, that looking really happy at the airport is often inconvenient. Someone might become suspicious and require you to take a drug test. Be cautious!

Now you're ready for the biggie. It's time to examine how to fly an instrument approach. We'll first take a look at VOR approaches, then we'll examine the details of flying an ILS (Instrument Landing System) approach. You've traveled a long journey in developing your flying skills. Be proud of what you've accomplished, but be prepared to be wowed by what's coming next.

CLASS 16: INSTRUMENT APPROACHES

Okay, time to sit back in your easy chair, grab a soda, and get prepared to sip and learn. That's right, get comfortable, because this lesson will consist mainly of a friendly little discussion about the principles of instrument flying. No, nothing super-secret is going to happen. No special handshakes. No passwords. Specifically, we'll talk about what an instrument approach is and why, when, where, and how it's done.

VFR vs. IFR Flying

In our earlier classes, we spent a great deal of time learning how to fly the airplane visually by looking at the horizon through the window. Pilots refer to this as flying VFR, which stands for flying under Visual Flight Rules. But what happens when you can't see the horizon, such as when clouds are present? Can you still fly? Yes, you can fly IFR, otherwise known as flying under Instrument Flight Rules.

IFR flight allows you to fly in the clouds using your airplane's instruments to maintain control of the airplane and using

your navigation equipment (such as VOR) to take you to another airport. This can all be done in the clouds without having to see outside, at least until you're ready to land the airplane, that is. Landing the airplane always requires that you see the runway well enough to land (Yes, even if you carry a lot of insurance and wear a helmet with a roll bar, you still need to see outside to land).

To fly instruments, pilots need an instrument rating, which is obtained after acquiring the private pilot certificate. It requires additional training in such things as maneuvering the airplane by its gauges, advanced navigation, and so on. (And you must also promise not to tell other pilots how much fun it is, or everyone will want to do it). The bulk of instrument training deals with learning to scan the instruments, just like you practiced in the three scan lessons already covered.

You're now ready to move beyond the instrument scan. You're ready for the next level, which, with some software programs, requires that you slay an enormous fire-breathing, multieyed beast.

CLASS 16: INSTRUMENT APPROACHES

Well, not today. Reholster your laser-phaser and sip that soda, Yoda, because we're going to learn how to fly a full-blown instrument approach.

Instrument Flying: The Big Picture

Instrument flying works this way. First, a pilot files an IFR flight plan with air traffic control (ATC). This is like making a dinner reservation at a fancy restaurant in that it alerts the restaurant staff to reserve space for you. Same with ATC. After the plan is filed and you're ready to go, you typically call the air traffic control tower at your departure point and tell them you have a flight plan on file. They say, "Okay, we've accepted your flight plan and you're cleared for takeoff." It's pretty simple, and, unlike a restaurant, you aren't expected to leave a tip.

With flight plan and clearance in hand, you depart, climb into the clouds (if clouds are present), and head on your way. Your objective is to follow the airways aloft to your destination. These airways are constructed from VOR courses that crisscross the country. How do you know which routes to follow? The same way you know which highway to

take when you travel on vacation—the roadmap. Pilots, however, use an aerial version of this roadmap that shows all these VOR routes along with their minimum altitudes. These altitudes keep you from getting so low that you knock birds out of trees and people off buildings.

All the while, ATC and its big fancy radar is keeping track of you and anyone else who happens to be flying IFR in your vicinity. If airplanes get too close, the radar controller separates the airplanes with verbal commands. No, not commands like, "Hey, look out!" The controller simply vectors airplanes (gives headings to fly) away from each other until the collision danger has passed.

As pilots approach the destination, they reach into their flight bag and bring out a special piece of paper that seems thin enough to be a Kleenex (but don't blow your nose with it, or the passengers will think Zamfir, master of the pan flute, is flying the airplane). The paper I'm referring to is called an instrument approach chart. It contains detailed instructions on how to leave the en route portion of the flight, approach the airport, and land, all

CLASS 16: INSTRUMENT APPROACHES

the while using some means of electronic navigation (typically VOR). Most big airports have one or more of these instrument approaches (and charts). Figure 16-1 shows a typical VOR instrument approach chart.

The Approach Chart

Instrument approach charts have several things in common. First, at the top, they show the frequencies you'll use to talk to the local air traffic controllers (section A). Below this is a plan view, which shows the electronic navigational aids that you'll use to fly to the airport (section B). Below that is something known as the profile view, which gives you a few of the preliminary minimum altitudes you'll use as you descend to the airport (section C). Finally, at the bottom, is the minima section (section D). This shows you the minimum altitude to which you can descend as you fly toward the airport.

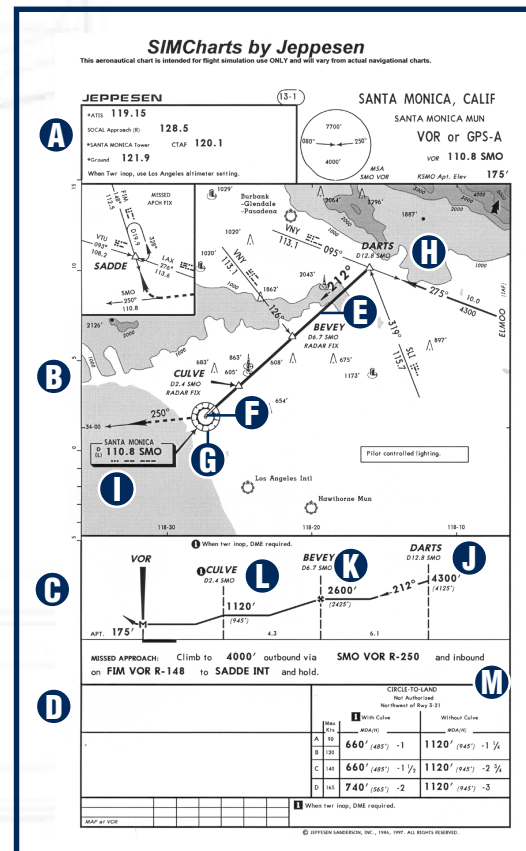


Figure 16-1

CLASS 16: INSTRUMENT APPROACHES

There is a point known as the missed approach point, or MAP, and it's shown on all approach charts. At the MAP, the pilot must see the runway clearly enough to land. This point is normally shown by the symbol "M" in the profile section (section C). If you can't see the runway clearly enough from the MAP, you must make a missed approach. This means you'll most likely go to another airport that has better weather.

Now that I've marinated your noodle with these ideas, I'm sure you're curious about how to fly an instrument approach. Let's find out. While there are several common types of instrument approaches, let's examine the most common one first. It's called the VOR approach.

The VOR Approach

Figure 16-1 shows the VOR approach chart for Santa Monica, California. Look at the thick black line located in the plan view (position E) running from right to left down toward the airport. This is the instrument approach course that takes

you to the airport (position F). Located on the airport is the VOR station (position G) that provides the navigation signal for the approach. Here's how you'd fly this approach.

Let's assume your airplane is located at DARTS intersection (position H). This intersection shows the beginning of the VOR approach course. All instrument approach courses are identified by thick black lines in the plan view section. Notice that the VOR approach course consists of the 212-degree VOR course to the Santa Monica VOR. Your job is to get on that thick black line and fly the depicted course to the airport. And while you're tracking this course, you're also descending to the lowest altitudes, as shown in the approach chart's profile section (position C).

So how do you get onto this approach course in the first place? ATC will either give you radar vectors (headings) to intercept the thick black line, or you can fly a VOR course that leads you to it (more on this later).

CLASS 16: INSTRUMENT APPROACHES

Flying the Santa Monica VOR Approach

To fly the 212-degree course to the VOR, tune your navigation receiver to 110.8 MHz (Santa Monica's VOR frequency, position I), and then set your OBS to 212 degrees. Heading 212 degrees will align you with the approach course. From here, you begin tracking the 212-degree course to the airport.

The profile section shows that once you're past DARTS intersection, you can descend to an altitude of 2,600 feet (position J). Many airplanes have Distance Measuring Equipment (DME). If yours does, you can obtain a DME reading from the Santa Monica VOR. As you approach the VOR, the DME counter shows your distance from the VOR decreasing. When the DME shows 6.7 miles, you're at BEVEY intersection (position K). Now you can descend to 1,120 feet. What's the reason for making descents in steps? You're kept above the higher obstacles located along

the approach course. As you get closer to the airport, the obstacles usually aren't as tall (apparently, other pilots have already knocked the bigger ones down). Therefore, you're progressively lowered on the approach course as you approach the runway.

Finally, when the DME reads 2.4 miles, you're at CULVE intersection (position L). Since no lower altitudes are shown in the profile view, you need to go to the minima section (position D) for the final and lowest altitude to which you can descend. The minima section shows 660 feet as the minimum descent altitude (MDA). To go any lower, you must have the airport in sight. You must have at least the one-mile visibility shown in the minima section next to the 660 feet to go any lower.

If you don't have the airport in sight by the time you fly over the VOR, you're required to execute a missed approach. Therefore, if the VOR flag flips from TO to FROM and you don't have the airport in

CLASS 16: INSTRUMENT APPROACHES

sight, you must fly the missed approach procedure (position M). This procedure takes you to a safe altitude from which you can plan your next approach.

A Variation of the VOR Approach

There are several variations to the VOR instrument approach procedure. Once you master these, you'll have no problem interpreting any approach chart. For instance, Figure 16-2 is the VOR approach to Long Beach, California (you'll notice that there is a slight difference in chart format between Figure 16-1 and 16-2. Within the next couple of years, all approach charts will eventually change to the format shown in Figure 16-2). The approach consists of two main segments. The first segment is the 300-degree course to the SLI VOR (tune the VOR to 115.7 MHz, and set the OBS to 300 degrees). The minimum altitude along this route is 1,500 feet, as shown by position A.

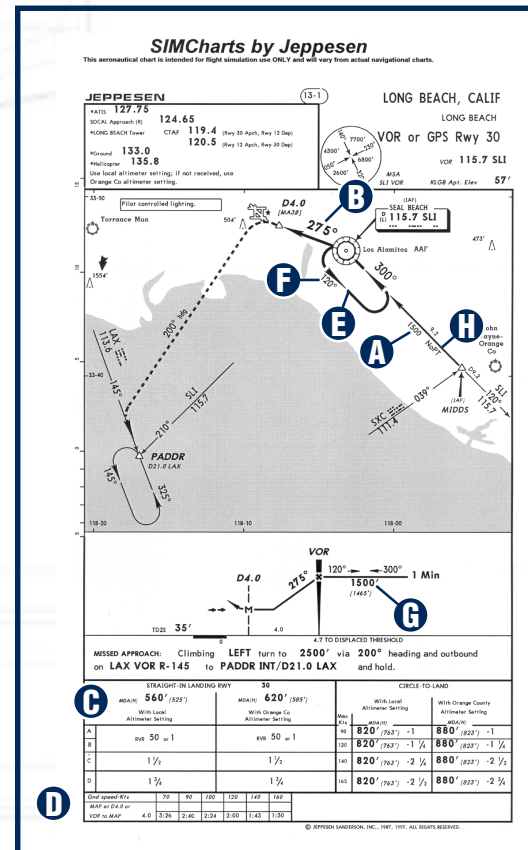


Figure 16-2

CLASS 16: INSTRUMENT APPROACHES

Once the TO/FROM flag flips and reads FROM, you need to turn and track outbound on the 275-degree course that leads you to the airport (position B). Since the profile doesn't show any minimum altitudes for this section of the procedure, look at the minima section of the chart (position C). You're allowed to descend to 560 feet on this approach. Where's the missed approach point? It's based either on time (start your watch at the VOR and count down the time for a given groundspeed) or a DME reading from the VOR. Both of the missed approach points are shown by position D.

The Racetrack Course Reversal

One last note on this approach chart. Notice the racetrack pattern shown in the profile view (position E). This is one of two means of course reversal (also known as a procedure turn). If you're heading to the VOR from the north, it's

too sharp a turn to cross the VOR and fly the 275-degree course toward the airport. Therefore, you should cross the VOR and reverse course. Flying a heading of 120 degrees (position F) allows you to go opposite the inbound course. From here, you'll turn to intercept the 300-degree course to the VOR, and fly the 275-degree course toward the airport once you've crossed the station.

Simply stated, your objective is to try and stay within the boundaries of the racetrack as you reverse course. Outside these boundaries, you're not given protection for terrain. Of course, in a simulator, this is no big deal. You may conk a few simulated mountain goats on the head, but so what? Since we're practicing to develop real flying skills, however, let's pretend this is real. What's the minimum altitude to fly the racetrack course reversal? This is shown in the profile view as 1,500 feet (position G).

CLASS 16: INSTRUMENT APPROACHES

Therefore, if I'm heading down to SLI VOR from the north, I'll turn and fly a heading of 120 degrees after crossing the station. This should keep me close to the racetrack boundaries. After one minute (the time shown next to the racetrack in the profile view, position G), I'll turn left to intercept and track the 300-degree course back to the VOR and complete the instrument approach. Of course, this also assumes that I've previously set my OBS to 300 degrees. With slight simplification, that's pretty much how it's done in the real world.

As an additional note, there are routes leading to the VOR (called feeder routes because they feed you onto the instrument approach procedure) that don't require a course reversal. Position H shows one feeder route starting at MIDDS intersection and listing the letters NoPT, which stands for no procedure turn. Along this route, you should fly the instrument approach without doing the course reversal. In other words, fly directly to the VOR, and then to the airport.

The Barb-Type Course Reversal

The second type of course reversal is shown in Figure 16-3. This is known as a barb-type course reversal (or procedure turn). Let's assume you're approaching from ITMOR intersection (position A). This route leading to the RDD VOR consists of flying the 224-degree course (tune the VOR to 108.4 MHz, and set the OBS to 224). The minimum altitude along this route is 3,700 feet (position B). Once you cross the VOR, turn and track outbound on the 175-degree course, as shown by position C (you must now set your OBS to 175). The objective here is to travel outbound, reverse your direction, and then track inbound and fly the instrument approach course.

The profile view shows 2,000 feet as the minimum altitude for the procedure turn which should be completed within 10 nautical miles (nm) of the VOR (position D). As you're descending, you'll travel outbound and, while still within 10 miles, you can turn to a heading of 220 degrees (position E). Fly this heading for a

CLASS 16: INSTRUMENT APPROACHES

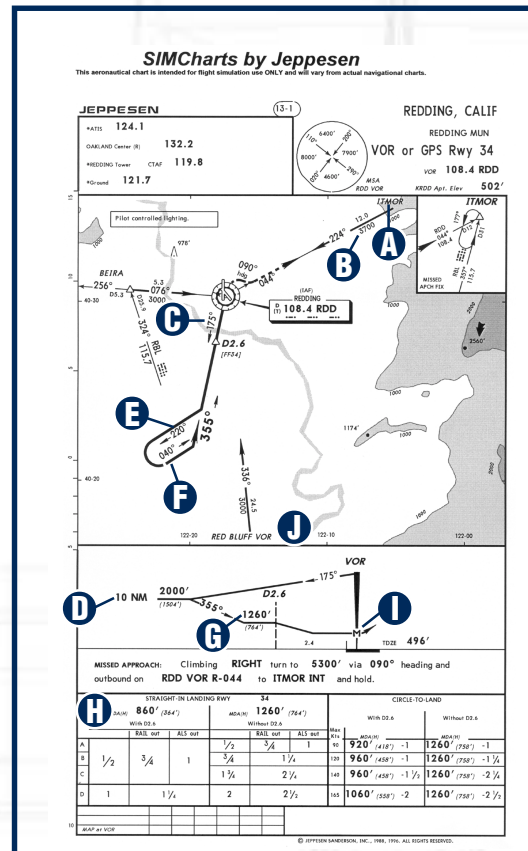


Figure 16-3

minute or less, and then turn left to a heading of 040 degrees (position F) and intercept the approach course inbound. This means you must reset your OBS to track to the VOR (turn the OBS to 355 degrees). Once inbound, you may descend to 1,260 feet (position G). When your DME (from RDD VOR) reads 2.6 miles, you can descend to 860 feet, which is the altitude shown in the minima section (position J). The “M” shown in the profile section (position H) depicts the VOR as the missed approach point.

Notice the two feeder routes leading from ITMOR and RED BLUFF VOR to RDD VOR (positions A and I). Feeder routes are shown as slightly thinner than the instrument approach course, and they are always accompanied by minimum flyable altitudes. Neither of these routes lists the letters NoPT. Therefore, as you approach RDD VOR along any of these routes, you must fly the procedure turn as a means of reversing course before flying the instrument approach procedure.

CLASS 16: INSTRUMENT APPROACHES

From the Red Bluff VOR (position I), track to the RDD VOR on the 336-degree course (set OBS to 336), and then make a left turn after crossing the VOR and track outbound on the 175-degree course from the VOR. Then, you repeat the same course reversal process listed above.

Did you get all that? I just took you through a quick course on VOR instrument approaches, something that usually takes instrument pilots months to understand. You can get started by flying the Lesson on VOR approaches in the Instrument Lessons. If you want to put an ice pack on your cranium, I'll understand. But believe it or not, there's only one more approach you need to look at in order to have a general idea about how most instrument approaches work. It's called the Instrument Landing System (ILS). While we already covered flying the ILS, let's talk a little bit about setting yourself up for the approach.

The ILS Approach

The ILS consists of two electronic beams: one provides horizontal guidance; the other, vertical guidance. What makes this

approach more useful than a VOR approach is that it takes you directly to the runway and sets you up for a landing from a comfortably low altitude. The VOR (and other approaches) just take you over the airport, sometimes at hundreds of feet above the runway. This, of course, makes it more difficult to transition from the instrument approach to the actual landing. The localizer portion of the ILS is much more sensitive than the VOR course. By sensitive, I don't mean it will cry if you yell at it. I mean that the needle response to course deviation is quicker than that of a VOR. This makes it a little more challenging to keep the needle centered in the display (Note that the glideslope needle is also quite sensitive).

Figure 16-4 shows the ILS Runway 28R approach chart for Portland International Airport (position A). The localizer frequency is 111.3 MHz (position B). Tuning this frequency in your number one navigation receiver (NAV 1, the top receiver in the stack of two), sets the VOR display to track one and only one specific course that's precisely aligned with the runway. This is called the localizer course, and, in the case of Portland, it's aligned in a direction of 279 degrees (position C).

CLASS 16: INSTRUMENT APPROACHES

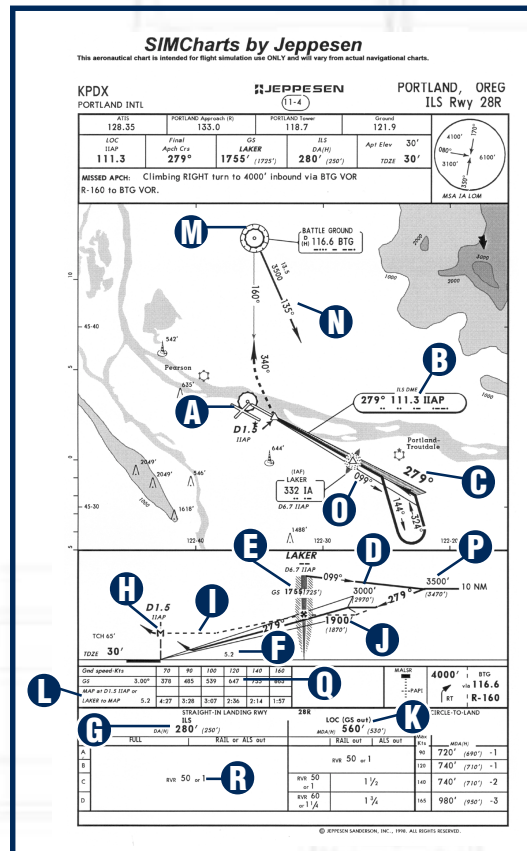


Figure 16-4

Once the localizer frequency is tuned in, you can set the OBS to the inbound course for a heading reference (although the OBS is nonfunctional, since the VOR receiver is now tuned specifically for the localizer course only). Tuning in the localizer automatically activates a specific glideslope frequency, which is not shown on the approach chart.

Let's assume that you're at 3,000 feet (the glideslope intercept altitude) at position D. You're flying a heading of 279 degrees, and the glideslope needle located within the VOR display is above the center position. This means you're below the glideslope. As you maintain 3,000 feet, the glideslope needle will eventually center (meaning you've intercepted it). Now you can begin your constant rate descent as we've previously discussed.

Instead of making the step-like descents as you did with the VOR approach, the ILS allows you to follow an electronic beam down to the missed approach point while avoiding all obstructions in your path.

CLASS 16: INSTRUMENT APPROACHES

As you begin your descent on the glideslope, you'll fly over the outer marker, shown by the feathered vertical area in the profile (position E). This activates a blue marker beacon-light in the cockpit (and an alarm that sounds just like the beeper that goes off when the fries are done at your local burger joint). The outer marker notifies you that you're at a specific point along your descent (5.2 miles from the runway, as shown in the profile view at position F).

How low can you go on the ILS? All the way down to decision height, or DH, which is 280 feet, as shown at position G in the minima section. DH is your missed approach point, and if you don't have the runway in sight by this point, you must execute a missed approach. Yes, I know there is an "M" shown at the beginning of the runway (position H). Sometimes pilots elect to fly this approach without using the glideslope. They do so because they don't have a glideslope receiver or the glideslope isn't working at the airport (someone may have yelled at it, hurt its feelings, and now it won't work). Therefore, the dashed line (position I) in the profile view shows the MDA for the localizer approach, just like the step-down

altitudes you saw on the VOR approach. If I were cleared for a localizer approach, I'd cross the outer marker at 1,900 feet (position J), descend to 560 feet (position K), and fly to the MAP. The MAP is identified by time (based on a specific groundspeed from the outer marker) or by DME on the localizer, as shown by position L.

Most everything else about this approach chart should now be familiar to you. For example, suppose you're over Battle Ground VOR (position M) and ATC clears you for the approach. The feeder route from BTG to the ILS is the 135-degree radial (position N). Set your VOR to track outbound on this radial until the localizer is intercepted. How will you know that you've intercepted the localizer? You can set one navigation radio (the bottom one) to navigate from BTG VOR and the other navigation radio (the top one) to receive the localizer. As you track from BTG VOR, you'll know you're over the localizer when the localizer needle centers. The outer marker beacon display will also activate in the cockpit as an additional clue, since the 135-degree course takes you to LAKER intersection (located on the localizer).

CLASS 16: INSTRUMENT APPROACHES

At LAKER, fly 099 degrees (position O), descend to 3,500 feet (position P), and make a procedure turn within 10 nm of LAKER. There is one important item you must know about localizers. Because the localizer is a single electronic beam, tracking opposite its inbound direction results in the needle appearing to read in reverse. In other words, when you are flying outbound from the localizer, if the localizer needle moves in one direction (right or left), you must fly in the opposite direction (left or right, respectively) to center it. This is known as reverse sensing. Therefore, as you prepare to fly the procedure turn by tracking outbound on the localizer, you'll have to fly opposite the direction the needle swings to keep it centered.

Once you've completed the procedure turn and are inbound headed 279 degrees, the needle will indicate normally. You may descend to 3,000 feet (the glideslope intercept altitude) once established inbound on the localizer and after making the procedure turn. Track the localizer, and fly the glideslope down to DA. We'll talk more about how to fly an ILS shortly.

That's a lot for such a short lesson, but at least you've been exposed to the fundamentals of flying instrument approaches. Perhaps you feel like you've been exposed to a concussion, too. Granted, it does take a little practice to get good at this. However, flying instrument approaches is a lot of fun. It's even addictive. So don't be surprised someday to find yourself undergoing instrument flying withdrawals if your computer breaks down.

CLASS 17: FLYING AN ILS APPROACH

Are you ready to rock and roll? If you thought landings were fun, wait till you get hooked on flying the Instrument Landing System (ILS) approach. We talked about it a little in the last class, but we'll go into more details here, since it's one of aviation's most challenging, yet satisfying, aerial activities.



Figure 17-1

An ILS approach consists of a descent to a runway using both vertical and horizontal electronic guidance. It's accomplished by following two needles (Figure 17-1) located in the ILS display on your instrument panel. Unlike other instrument approaches, this one takes you down to a height known as decision height (DH). DH is approximately 200 feet above the runway elevation, as shown in Figure 17-2.

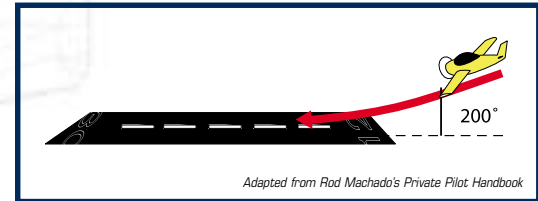


Figure 17-2

From this not-too-lofty perch, you take a peek outside and decide if you can see the runway well enough to land (thus the name decision height). If unacceptable runway visibility prevents a safe landing, you apply power, climb, and head off to someplace else with better weather. Let's take a closer look at how the ILS approach is constructed.

The ILS consists of two electronic beams. One beam is angled outward, and one is angled upward from the runway complex, as shown in Figure 17-3. The outward (horizontal) beam is called the localizer. It helps align your airplane with the runway. You track the localizer by following the needle shown in Figure 17-1 (position A). If the needle is to the right, you go to the right; if it is to the left, you go to the left. A needle that remains centered means your airplane is tracking the runway centerline. Under no-wind conditions, you need only fly the runway heading to keep

CLASS 17: FLYING AN ILS APPROACH

the localizer needle centered. If there's wind, you need to make small corrections to compensate for wind drift. Sounds easy, but it does take practice to perfect this skill.

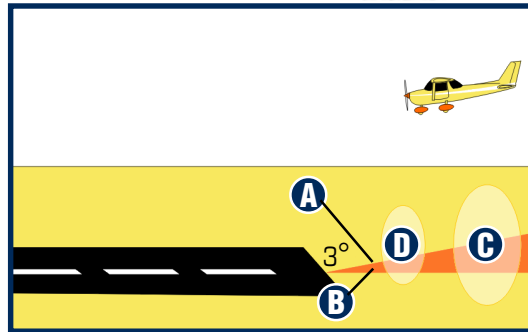


Figure 17-3

The glideslope is an electronic beam that's tilted upward at approximately a 3-degree angle (Figure 17-2). By centering the glideslope needle, shown in Figure 17-1 (position B), you're flying an obstruction-free path down towards the runway. How do you keep the glideslope needle centered? Fly towards it just like a localizer needle. If the needle swings upward, then fly upward; if it swings downward, then fly downward. The objective is to

maintain the specific rate of descent that allows the airplane to track the glideslope down to DH.

The Constant Rate Descent

For a typical ILS approach flown at 90 knots, a 500-foot-per minute (FPM) descent rate is required to remain on glideslope. Of course, if you fly the approach at a faster speed, you must increase your descent rate. Glideslope angle and wind are two factors that affect the precise descent rate required to center a glideslope needle.

Let's suppose you want to fly a descent at a constant rate of 500 FPM at 90 knots (this is a typical profile that you'll use to fly an ILS approach). How should you go about doing this? First, you'll do this by reducing power from its present setting to 1600 RPM and let the nose naturally pitch down slightly. Then, you'll adjust the pitch as necessary to maintain a descent rate of 500 FPM and adjust the power to maintain 90 knots of airspeed. Yes, this is a reversal of the control functions we used in a previous lesson. Using the controls in this manner allows you to maintain precise control of the descent rate required for an ILS approach.

CLASS 17: FLYING AN ILS APPROACH

Here's how the sequence should look.

1. Adjust power to maintain 90 knots in level flight. A speed of 90 knots requires a pitch attitude of approximately 6 degrees nose-up pitch in level flight.
2. Reduce power to 1600 RPM, let the nose pitch forward naturally, and adjust the pitch to maintain a 500 FPM descent rate. This requires approximately 3 degrees nose-up pitch on the attitude indicator (AI).
3. Trim to maintain the attitude for this descent rate.
4. Make small adjustments in power to maintain 90 knots (airplanes have inertia, so it may take a few seconds to change speed when moving the throttle. Be patient).

Believe it or not, this is precisely what you'll do when intercepting the glideslope. Since glideslopes are normally intercepted from below, you'll fly level at 90 knots until the needle lowers to a center position in the ILS display (Figure 17-4). Once centered, you'll reduce power to approximately 1600 RPM, adjust the pitch, and trim the airplane for a 500

FPM descent rate, maintaining 90 knots. Assuming you're in perfect harmony with the universe, the airplane will remain on glideslope all the way to DH. But you know how easy it is to get a kink in your chakra, so you can't count on your karma being perfect. Therefore, you'll need to make slight variations in descent rate to keep the glideslope needle centered. Let's examine this.



Figure 17-4

Let's assume you're above the glideslope and must increase your descent rate to capture it. If you want to change the descent rate from 500 to 700 FPM, you'll need to place the airplane in a 3-degree nose-down pitch attitude, as shown in Figure 17-5. You'll need to reduce power to keep the airspeed at 90 knots.

CLASS 17: FLYING AN ILS APPROACH



Figure 17-5

The secret to maintaining a specific rate is not to chase the VSI needle. Simply place the airplane at the precise attitude on the AI, and then make small pressure changes on the joystick to adjust the rate of descent.

Let's assume you've captured the glideslope and want to change the descent rate back to 500 FPM. Do so by increasing the pitch to 3 degrees nose-up and increasing power to approximately 1600 RPM.

Now assume you're below the glideslope and must decrease your descent rate to capture it. Change the descent rate from 500 to 300 FPM by placing the nose in a level pitch attitude, as shown in Figure 17-6. Increase the power to approximately 1700 RPM to maintain 90 knots.



Figure 17-6

Remember, don't chase the VSI needle. Make pitch changes on the AI, followed by small pressure adjustments on the joystick to fine-tune the VSI's indication.

CLASS 17: FLYING AN ILS APPROACH

Radial-Scanning Primary Instruments

ILS approaches are not the place to catch a little shut-eye. Following the ILS needles to decision height is a demanding task. That's why you never leave Step 2 of the three-step instrument scan. In other words, you spend almost all of your time radial-scanning the primary instruments for a constant rate descent. Figure 17-7 shows the primary instruments for an ILS approach. The VSI is primary for pitch; the HI is primary for bank, and the AI is primary for power. These instruments are radial-scanned along with the ILS display (you don't, however, need to radial-scan the airspeed indicator that often).



Figure 17-7

Therefore, three instruments are continuously radial-scanned when flying an ILS, with other instruments occasionally included. Things are far too busy to perform the monitor scan found in the final step of the three-step scan.

Additionally, not all glideslopes are created equal. Some are angled differently than others. Therefore, they may require different descent rates based on the airplane with which they are flown. Figure 17-8 shows the descent rates versus different groundspeeds required to fly various glideslopes based on this approach. At 90 knots, for this 3-degree glideslope, a 485 FPM descent rate should keep you right on target. Now it's your turn.

CLASS 17: FLYING AN ILS APPROACH

RATE OF DESCENT											
Angle of Descent (degrees and tenths)	Ground Speed (knots)										
	30	45	60	75	90	105	120	135	150	165	180
3.0	160	240	320	395	485	555	635	715	795	875	955
3.5	185	280	370	465	555	650	740	835	925	1020	1110
4.0	210	315	425	530	635	740	845	955	1060	1165	1270

Figure 17-8

If you're having trouble tracking the localizer, look at the runway ahead of you and visually align yourself with it. Observe how easy it is to fly a constant heading when looking at an actual runway. Why is it easier? Because you get pitch, bank, and alignment information in one "over-the-nose" picture. When you can't look outside, it takes a trained instrument scan to acquire the same information from three different instruments: the AI, the HI, and the ILS display, respectively.

A Few Important Secrets

Now you have the basic idea about how ILS approaches are flown. So here's what the pros know. First, the most important instruments to radial-scan are the HI and the VSI. It's not necessary to radial-scan the airspeed indicator nor the ILS display every time. In fact, you might limit your radial-scan of the airspeed indicator to, perhaps, once for every 10 radial-scans of HI and VSI. You can also reduce your radial-scan of the ILS display to once

CLASS 17: FLYING AN ILS APPROACH

every three scans of the HI and VSI. Of course, you want to take in the altimeter, tachometer, and other assorted instruments on occasion, as time permits. Once you've found a heading and a descent rate that allows you to track the ILS, you must fly those values precisely until you have a reason to change them. And I do mean precisely. Good instrument pilots can hold a heading to a single degree and a descent rate to within plus or minus 25 FPM. Honest! But it does take a lot of practice.

In turbulence, it's easy to have your heading and VSI indication bouncing all around. In these situations, it's best to fly averages. Do this by relying more on the AI for pitch and bank control. Find the pitch that allows for the approximate desired descent rate. Fly this pitch and keep the wings level on the AI.

Additionally, it's sometimes necessary to make small, but jerky, motions on the joystick when flying a simulator. Unlike the actual airplane, you can't sense a change in pressure on the flight controls. This prevents you from anticipating a change in attitude. Furthermore, airplanes have rudders, which help fine-tune the airplane's directional control. You may not have rudders available with your simulator hardware. In that case, small, jerky motions on the joystick are sometimes necessary to keep the airplane at precise attitudes. If you *do* have rudder pedals or a rudder joystick, keep your motions nice and smooth!

Wind Correction on the Localizer

As a teenager, I recall the first time I told my dad that I needed some space. He locked me out of the house and said, "Now you've got all the space you need." At that precise moment, I understood the power of feedback. Feedback changed my behavior; as I know it will change yours, especially in reference to flying the localizer.

CLASS 17: FLYING AN ILS APPROACH

When you first begin flying the ILS, head the airplane in the direction of the localizer. In the case of Oakland, the localizer direction is 294 degrees. Fly 294 degrees, and watch the needle's movement. You want feedback in the form of localizer needle movement. In particular, you want to know which way and how much the needle moves as you hold 294 degrees.

The movement of the localizer needle tells you two things: wind direction and wind speed (determined by how fast the needle moves). Once the needle moves from its center position (use a one-dot horizontal deflection), recenter it using a 5- to 10-degree intercept angle (IA). The smaller the intercept angle, the less likely it is that you'll overcorrect. Of course, if you use a 10-degree intercept angle and the needle doesn't move back to center or moves farther from center, then a larger intercept angle is necessary. You also know that you'll need at least a 10-degree wind-correction angle once you're reestablished on the localizer.

Once the localizer needle is centered, apply a small correction for wind. Try a 1-, 5-, or 10-degree wind-correction angle (WCA) based on your best estimate of the winds. With the WCA established, watch the localizer needle. If it returns to center, you know that the WCA is an angle between the WCA and the localizer direction.

For instance, upon intercepting the localizer at Oakland, you fly 294 degrees. In a few seconds, the localizer needle begins moving to the left. You fly a heading 10 degrees to the left of 294 degrees, or an IA of 284 degrees, to reintercept the needle. When the needle recenters, you apply a 5-degree WCA to the left of 294 degrees (289 degrees). If this WCA works, the needle will stay centered. If not, repeat the process using smaller heading changes to recenter the needle. This technique is called bracketing, and it's the technique all professional pilots use (with slight modification) to center VOR and localizer needles.

CLASS 17: FLYING AN ILS APPROACH

Practicing this technique is sure to save you embarrassment during later flights. The last thing you want is the localizer needle banging against the instrument case. That's when the passengers start asking those annoying little questions like, "Hey, what's that clicking noise? You got your blinker on, Bud? Is that a time bomb, or what?"

Go now to the Lesson on ILS approaches. You'll have fun—trust me!

CLASS 18: HOLDING PATTERNS

You already learned how to fly a traffic pattern in a previous class. So what's the difference between flying a traffic pattern and flying a holding pattern? Well, you noticed that when you were flying a pattern, it was something you did visually. The hold patterns you will learn in this class are done exclusively during instrument flying.

When an airline captain comes over the intercom and says, "Umm. . . looks like we're gonna have to hold here for a while," you probably groan and think, "Great. A delay." Well you know more about instrument flying than you think you do, because that's exactly what holding is designed to do—delay an aircraft. An airplane can't just pull over to a rest area when ATC needs to delay its arrival somewhere because of traffic congestion or weather conditions. So the controller tells the pilot to fly a holding pattern.

Hold That Pattern!

A standard holding pattern looks like an oval racetrack anchored at a holding fix (a VOR, nondirectional radio beacon [NDB], or intersection), as shown in Figure 18-1. The two straight legs are called the inbound and outbound legs.

In a standard holding pattern, you make all turns to the right (nonstandard patterns, therefore, have left turns). All turns should be at standard rate. How long are the legs of the pattern? Long enough so that flying the inbound leg will take about one minute. Wind will affect the leg length—so if there's wind, you need to adjust the length of the outbound leg so the next inbound leg will also take a minute.

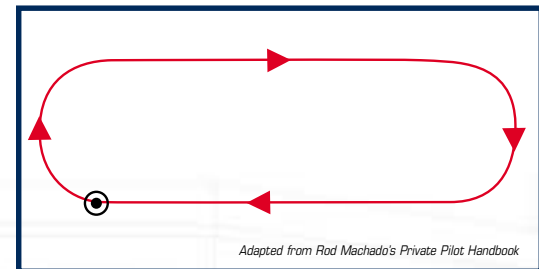


Figure 18-1

Actually, flying a holding pattern is pretty easy, but figuring out how to enter one is something most pilots dread. To keep airplanes within protected airspace, the FAA recommends specific entry methods. Which entry method to use depends on your heading when you initially cross the holding fix.

CLASS 18: HOLDING PATTERNS

Direct Entry

Use a direct entry when approaching the holding fix in the same direction as the inbound leg (area C in Figure 18-2). Fly to the fix and turn right (standard holding pattern) or left (nonstandard holding pattern), and proceed with the holding pattern.

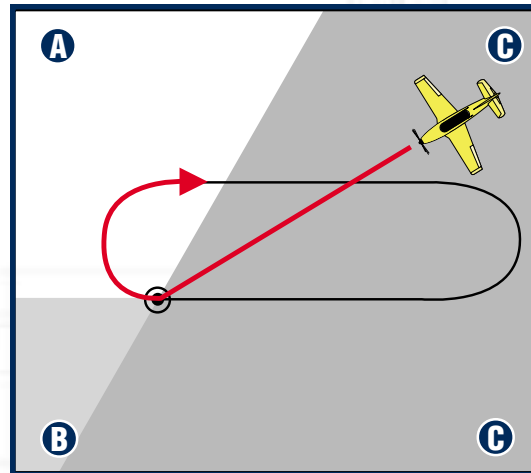


Figure 18-2

Adapted from Rod Machado's Private Pilot Handbook

Parallel Entry

Use a parallel entry when approaching the holding fix in the opposite direction as the inbound leg and ending up outside the racetrack after crossing the fix (area A in Figure 18-3). Turn parallel to the inbound course, fly outbound for one minute, and then turn toward the racetrack to intercept the inbound course. Return to the fix, and proceed with the holding pattern.

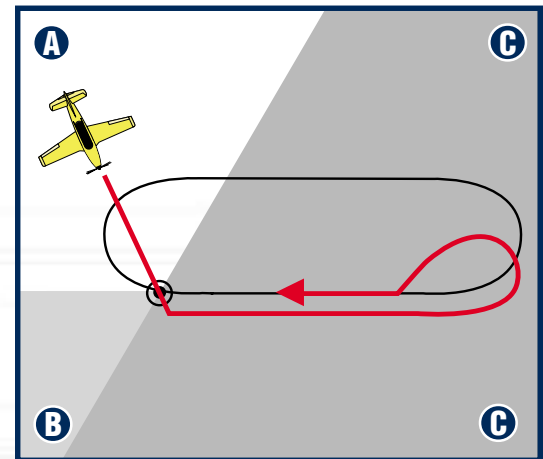


Figure 18-3

Adapted from Rod Machado's Private Pilot Handbook

CLASS 18: HOLDING PATTERNS

Teardrop Entry

Use a teardrop entry when approaching the holding fix in the opposite direction as the inbound leg but ending up inside the racetrack after crossing the fix (area B in Figure 18-4). At the fix, turn toward the racetrack to a heading that's 30 degrees off the outbound leg heading. Hold that heading for one minute, and then turn in the opposite direction to intercept the inbound course. Return to the fix, and proceed with the holding pattern.

Sound complicated? Most pilots think so. Luckily, a simple, direct entry is the most common entry type, since a controller will usually tell you to hold as you approach an intersection along your route of flight. Practicing holds is a great way to exercise your instrument flying skills, and should the day come when a controller tells you to hold, you'll know what to do. Right now, take the Lesson on holding patterns. Then, strut your stuff for the examiner in the Instrument Rating Checkride.

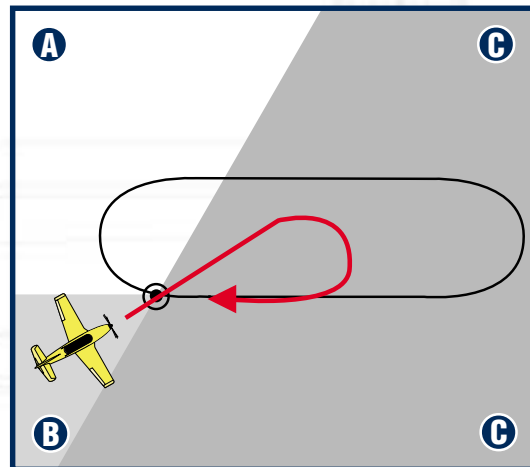


Figure 18-4

Adapted from Rod Machado's Private Pilot Handbook

CLASS 18: HOLDING PATTERNS

Final Thoughts

If you've completed all these lessons, you've impressed me in several ways. First, you showed tremendous motivation, which I liken to Captain Ahab going after Moby Dick and taking the tartar sauce along. Ahab was motivated, just like you. While many of your brother and sister Flight Sim users were out buzzing bridges and skidding off aircraft carriers, you were studying. Additionally, you've delayed your gratification and have earned basic flight skills as a result. I'm impressed. While these skills won't replace actual airplane skills, they come close.

Remember, this is only the beginning. Consider taking a flight lesson in an actual airplane. Do it for no other reason than to see how much you really learned. Who knows? In the next few years, it may be you taking me for a ride in your airliner.

Bon Voyage!

A handwritten signature in black ink, reading "Rod Machado". The signature is stylized with a large, looping "R" and a cursive "Machado".

INDEX

A

abeam 125
adjusting for landing 67
aerodynamics 52
aeronautical
 charts 122
Aeronautical Information Manual 83
aft 97
AI 172
aileron
 crosswind 116, 119
 landings 116, 119
 trimming 21
ailerons 10
air traffic control (ATC) 156
airport, signs 79
airspeed 38
 drop in as indication of climbs 36
 effect on nose position 34
airspeed indicator
 green arc 60
 radial-scanning 144
 white arc 73
altimeter 17
 how to read 44

angle of attack 47, 50, 91, 101
 increasing 54
apparent weight 101
approach chart 157
artificial horizon line 25
attitude 42, 135
attitude indicator 14, 136
 degrees of pitch 37
 miniature airplane 24
 orange pointer 41
 vertical calibration 36
autorudder 26, 30
axes 10
 lateral 10
 longitudinal 10
 vertical 10

B

bank control 21
bank marks 23
barb-type course reversal 162
base legs 110
Bernoulli 92
Bernoulli's principle 54
Big-6 instruments 136
blue marker beacon-light 166

INDEX

C

- charts, sectional 122
- chord line 47
- climbing 31
- climbing and descending turns 140
- Cockpit view 70
- Common Traffic Advisory Frequency (CTAF) 86
- compass cards 123
- constant rate descent 169
- control tower 86
- controlled airports 86
- course deviation indicator (CDI) 123
- crab method, see crabbing 115
- crabbing 115
- critical angle of attack 91, 92
- crosswind drift 115
- crosswind landings 115
- crosswind legs, heading 108
- cruise flight 57

D

- DA 167
- decision height (DH) 166, 168
- deflecting the joystick 23
- degrees of bank 23

- departure leg 108
- departure stalls 98
- descending 35
- descent from straight-and-level flight
 - Entering 139
- descent rate 169
- descent rates 40
- descents 19
- direct entries 178
- directional gyro 16
- displaced thresholds 89
- Distance Measuring Equipment (DME) 159
- downwind legs 109
 - heading 110
- drag 8, 51

E

- earth's horizon 13
- electronic beams 164
- elevators 11
- engine torque 60

F

- factors 35
- feeder routes 162, 166
 - leading 163

INDEX

final approach 63, 112
fixes
 holding 177
flags
 VOR 123
flap operating range 73
flaps 72
flare 63, 68
 effect of flaps on 77
flight plans
 IFR 156
flights
 coordinated 27, 29
Four Forces
 drag 7
four forces 7
 drag 8
 lift 7, 8
 thrust 7, 8
 weight 7, 8
“FROM” indication 123
full flaps to increase the airplane’s drag 74
full throttle 32

G

G-forces 99
glidepath 113
glidepaths 65
glideslope down 167
glideslope intercept altitude 165, 167
glideslope needle 164
glideslopes
 defined 169
go around 75

H

hat switches 13
heading
 airplane’s 16
 specific 16
heading indicator 16
 radial-scanning 144
 VOR navigation 125
high altitudes
 effect on power production 33
high temperatures
 effect on power production 33

INDEX

hold-short lines 85
holding fixes 177
holding patterns 177
horizons 14
horizontal component 22
horizontal guidance 164
hundred-foot hand 17

I

ILS approach 164
 detailed 168
inbound 177
inclinometers 28
index
 VOR 123
instrument approach charts 157
instrument approaches 155
Instrument Flight Rules 155
Instrument Landing System (ILS) 164
instrument rating 135
instrument scan 135
intercepting and tracking
 a VOR course 126
intercepting the localizer 166

J

joysticks 13
 neutral position 23

L

laminar airflow 92
landing attitudes 68
landing flares 63
landings 62
Lateral axis 12
lateral axis 10
leading edge 47, 51
left (nonstandard holding pattern) 178
left rudder 28
left turn 28
level flight 13
lift 8, 22, 31, 47
load factor 99
localizer course 164
localizer frequency 165
localizer needle 175
localizers
 defined 168
longitudinal axis 10
 aligning 117
lowered cambered surface 47

INDEX

M

magnetic compass points 81
magnetic North Pole 81
mandatory hold points 87
minima sections 157
minimum forward speed 32
missed approach point 158, 161, 166
monitor scanning 152

N

NAV 1 164
nose gear 71

O

OBS 165
omnibearing selector (OBS) 123
orange ball as a pitch reference 41
outbound 177
outer markers 166

P

parallel entries 178
pitch 10, 11, 38
 downward 14, 17
 upward 14, 17
plan view 157

power 42, 135
procedure turns 162
profile view 157, 161
propeller slipstreams 60

R

racetrack course reversals 161
racetrack patterns 177
radial-scanning 142, 173
radial-scanning primary
 instruments 172, 173
radials 133
radios
 Common Traffic Advisory
 Frequency (CTAF) 86
rate of climb 17
rate of descent 57
relative wind 48
 direction 49
 velocity 49
right (standard holding pattern) 178
right rudder 28
right turns 28
rotation 54
rudder 26, 78
 crosswind 116
 landings 116

INDEX

runway edge lighting 82
runway lighting 81
 centerline 83
 sequenced 82
runway markings
 arrows 88
 chevrons 88
runway safety area sign 88
runways
 markings 80
 numbers 80
runway's threshold
 45-degree angle 111

S

S-turns 114
Scanning 137
sectional charts 122
sideslip method 119
slow flight 46
stall 33
stall speed 32
stalling 46
stalls 91
 departure 98
 high-speed 94
 intentional 95
 recovery 93, 96

standard rate turn 148
steep turns 99
 bank angle 99
steering the airplane on the ground 78
Straight flight 13
Straight-and-level flight 13

T

tachometer
 radial-scanning 144
takeoffs 60
taxiing the aircraft 78
taxiway markings 83
taxiway signs 84
teardrop entries 178
three-step process for scanning
 your flight instruments 135
throttle position 41
Thrust 8, 31
"TO" indication 123
Top-Down view 109, 111
tracking in reverse 167
traffic pattern altitude (TPA) 108
traffic patterns 107
trailing edge 47, 53
tricycle-gear airplane 64

INDEX

trim 40
Trim tab 19
 direction 19
trimming 18, 20, 42, 135
 joystick 20
 keyboard 20
 specific airspeed 40
turn coordinator 28
turning 22

U

uncontrolled airport 86
upper cambered surface 47

V

VASIs 66
vertical axis 10, 27
vertical component 22
vertical guidance 164
Vertical Speed Indicator (VSI) 17
vertically 22
virtual cockpit 70
Visual Approach Slope Indicator (VASI) 66
Visual Flight Rules 155

VOR 158
 electronic courses 121
 Very high frequency
 Omnidirectional Range 121
VOR flag
 off 125
VOR navigation 121
VSI 154, 172, 173
 radial-scan 151

W

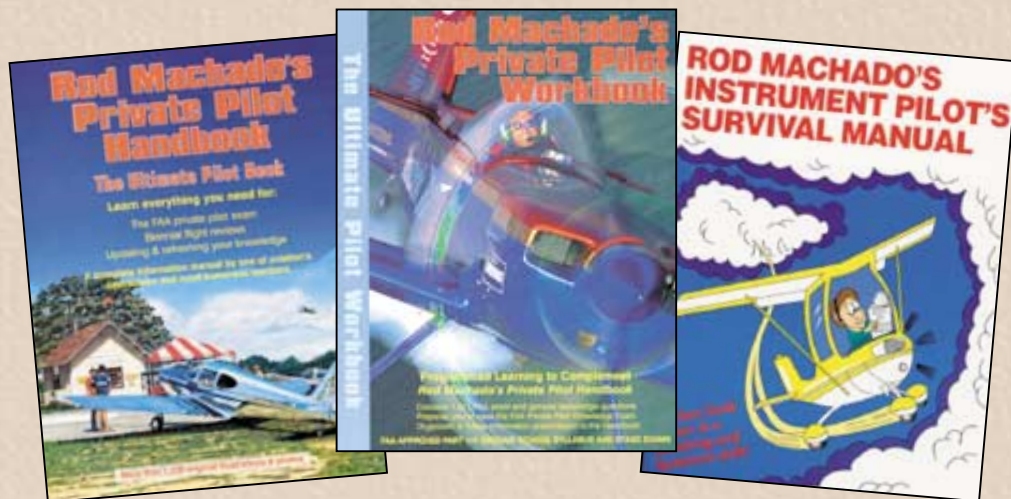
weight 8
wind correction 130, 174
wind direction 175
wind speed 175
wing 46
 angle of attack 25

Y

yaw 10, 27
 adverse 30

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